CHAPTER III - SUMMARY OF WESTERN NORTH PACIFIC AND NORTH INDIAN OCEAN TROPICAL CYCLONES

1. GENERAL

During 1986, JTWC issued warnings for twenty-seven tropical cyclones in the western North Pacific. This included three super typhoons, sixteen typhoons, eight tropical storms and no tropical depressions. This also included one typhoon, Georgette (11E), which initially developed in the eastern North Pacific. For the second year in a row the total number of western North Pacific tropical cyclones was four lower than the climatological mean of thirty-one. The total for the North Indian Ocean was three tropical cyclones (of tropical storm intensity), which is also less than the climatological mean of 4.5 and three less than the preceding year. In summary, warnings were issued on a total of thirty tropical cyclones in the northern hemisphere.

In WESTPAC there were 163 "warning days". (A "warning day" is defined as a day during which JTWC was issuing warnings on at least one tropical cyclone. A "two-cyclone" day refers to a day when two different tropical cyclones were warned on simultaneously, a "three-cyclone" day - three tropical cyclones at one time, and so on...). In WESTPAC, there were thirty-two two-cyclone days, four three-cyclone days and no four- or five-cyclone days. When North Indian Ocean tropical cyclones are included, there were 168 warning days, thirty-two two-cyclone days, seven three-cyclone days and no four- or five-cyclone days.

JTWC issued 743 warnings on the twenty-seven western North Pacific tropical cyclones and twenty-nine warnings on the three North Indian Ocean tropical cyclones, for a total of 772 northern hemisphere warnings. There were thirty-eight initial Tropical Cyclone Formation Alerts (TCFAs) issued for the western North Pacific and seven for the North Indian Ocean, for a total of forty-five. All WESTPAC and North Indian Ocean tropical cyclones (100 percent) developed after the issuance of a TCFA. For the western North Pacific, the false alarm rate was twenty-six percent (a ten percent improvement over last year) and the mean lead time (to issuance of first warning) was twenty-five hours. For the North Indian Ocean, the false alarm rate was 57.0 percent; the mean lead time was 5.7 hours.

2. WESTERN NORTH PACIFIC TROPICAL CYCLONES

Several factors made 1986 an unusual, and therefore difficult, tropical cyclone season for JTWC. There were only four classic "straight runners" (which normally have the lowest forecast errors) in 1986, as compared to the seven of 1985. The number of "recurvers" was the same, but there were three more tropical cyclones in the "other" category in 1986 than in 1985. "Other" tropical cyclones are those whose tracks do not easily fit into the straight runner or recurver categories, i.e., the erratic systems. The tropical cyclones in this last category were the most difficult to forecast. The major forecast problems arose with those tropical cyclones that formed in the active monsoon trough and during the extremely active winter period. For discussion purposes the tropical cyclone year is divided into three periods.

JANUARY THROUGH AUGUST

The season began in late January with Typhoon Judy (01W), a "classic" recurving system which passed between Guam and the Philippine Islands. Although JTWC did a good job forecasting the track, difficulties with the speed of movement caused forecast errors to be larger than average. Typhoon Ken (02W) was a short-lived tropical cyclone which formed southwest of Guam and dissipated over water. Super Typhoon Lola (03W) developed very slowly in the vicinity of Pohnpei in the Caroline Islands. The enhanced southwest monsoon flow associated with Lola's formation was significant, as indicated by damaging 60 kt 31 (m/sec) winds which were reported on Pohnpei. At the same time, and of particular meteorological interest, was the development of a "twin" tropical cyclone, Namu (33P), in the western South Pacific. This situation occurs periodically in the Western Pacific and Indian Oceans when strong low-latitude westerlies enhance the development of tropical cyclones in both hemispheres. This is usually observed during the spring and fall transition periods. Tropical Cyclone Namu (33P), incidentally, was the most intense tropical cyclone to strike the Solomon Islands this century. Tropical Storm Mac (04W) developed near the island of Hainan in the South China Sea and passed between Luzon and Taiwan at the end of May. As a monsoon depression, it struggled against strong vertical wind shear most of its life. Typhoon Nancy (05W) developed in June in the central Philippine Sea, struck the east coast Taiwan and recurved into the Korea Strait. JTWC forecast Nancy's recurvature track quite well until near the end, when it began to accelerate toward the northeast and central convection sheared away. Tropical Storm Owen (06W) was another relatively weak system which had difficulty developing due to strong vertical shear. The second super typhoon of the year, Peggy (07W), developed east of Guam and followed a west-northwest track into northern Luzon, where 93 deaths resulted. It continued onward until it made a second landfall on the China coast northeast of Hong Kong. Typhoon Roger (08W) was another one of the several early season recurving tropical cyclones. The recurvature near the island of Okinawa was accurately forecast 48-hours in advance. Tropical Storm Sarah (09W) was the first of a series of tropical cyclones which caused serious forecast problems for JTWC. Sarah (09W) developed in an active monsoon trough east of Luzon and appeared, from satellite imagery, to track west-northwestward across Luzon into the South China Sea. Post-analysis of aircraft reconnaissance data, however, indicated that the low-level center never made landfall on Luzon, but recurved northeastward instead. Typhoon Tip (10W) and Typhoon Georgette (11E) engaged in a classic binary interaction (Fujiwhara, 1921 and 1923; Brand, 1970; Dong and Neumann, 1983) northeast of Guam which resulted in larger than average forecast errors for both systems. Typhoon Georgette (11E), incidentally had one of the longest tracks on record. It initially developed in the eastern North Pacific, dissipated as a significant tropical cyclone in the central North Pacific, and then regenerated from the pre-existing disturbance in the western North Pacific. Typhoon Vera (11W) caused more forecast problems than any tropical cyclone in 1986. It generated in the active monsoon trough as a "classic" monsoon depression - difficult to position and forecast. Typhoon Wayne (12W) was probably the most interesting tropical cyclone in 1986. During its exceptionally long life (twenty days), it struck Luzon (once) and Taiwan (twice), threatened Hong Kong (twice), dissipated and reformed (once), before finally dissipating over North Vietnam near Hanoi. Many multiple-storm days occurred during the later part of this first period. As a result, reconnaissance (both satellite and aircraft) assets were working overtime to keep up with the requirements for the latest data.

SEPTEMBER THROUGH OCTOBER

The tropics quieted down somewhat during this second period. Typhoon Abby (13W) developed just to the southeast of Guam and moved northwestward before recurving near Taiwan. Typhoon Ben (14W) developed rapidly southeast of Guam and drifted northward before recurving through a break in the subtropical ridge. Typhoon Carmen (15W) was the third tropical cyclone in a row to develop southeast of Guam. It followed a recurvature track, passing north of Guam and east of Japan. The forecast statistics for Carmen (15W) were excellent.

During the rest of October and into early November, the major tropical cyclone generation area shifted, for the most part, from southeast of Guam to the Philippine Islands. Although Tropical Storm Dom (16W) did not become a "significant" tropical cyclone until it was approaching the coast of Vietnam, the Republic of the Philippines suffered extensive flooding when Dom (16W), at tropical depression intensity, passed by. Typhoon Ellen (17W) intensified east of the central Philippine Islands and passed about 90 nm (167 km) south of Subic Bay. Initially, it appeared that recurvature toward Taiwan would take place, but a surge in the low-level northeasterlies from the China mainland resulted in a more westerly track towards the island of Hainan. Further to the east, Typhoon Forrest (18W), which attained 100 kt (185 m/sec) intensity, developed northeast of Guam and recurved. Tropical Storm Georgia (19W) spawned just east of the central Philippine Islands, passed south of Subic Bay and made landfall over Vietnam after following a nearly straight track.

NOVEMBER AND DECEMBER

The combined months of November and December 1986 proved to be one of the most active winters in WESTPAC history with seven tropical cyclones (compared to an average of four). The three typhoons in December is an all-time record. Tropical Storm Herbert (20W) developed in the wake of Tropical Storm Georgia (19W) and followed an almost identical track westward across the South China Sea with landfall on the coast of central Vietnam. Tropical Storm Ida (21W) was hindered by the frictional effects during its passage through the central Philippine Islands and strong vertical wind shear over the South China Sea. Typhoon Joe (22W) formed east of Luzon and recurved to the northeast without making landfall. Its associated convective bands, however, produced significant rainfall over the northern Luzon. The tropical cyclone activity then shifted eastward. Super Typnoon Kim (23W) was the first in a series of four difficult late season tropical cyclones. It formed to the southeast of Guam and initially followed a northwestward track. Although Kim (23W) appeared to change to a recurvature track before reaching Guam, it abruptly turned toward the west and passed 15 nm (28 km) north of the island of Saipan in the Marianas at near super typhoon intensity, causing extensive damage. Tropical Storm Lex (24W) developed in the wake of Kim (23W) but was unable to mature due to the strong upper-level shear caused by the intense outflow from Kim (23W). Typhoon Marge (25W) also developed southeast of Guam, but very slowly. It turned westward, passed south of Guam, then crossed the central Philippine Islands and dissipated in the South China Sea. Typhoon Norris (26W) continued the late season trend by developing to the southeast of Guam. It oscillated about a westward track and crossed the central Philippine Islands before dissipating over the South China Sea.

The last three typhoons of the year - Kim (23W), Marge (25W) and Norris (26W) were similar in that they followed a "step-like" track. It appeared that the basic steering flow south of the subtropical ridge axis changed the tracks from a westward to more northwestward, as mid-latitude troughs moved off China. Once these troughs had passed to the north, the tracks reverted back to westward. The mid-latitude troughs never penetrated far enough to the south to break through the subtropical ridge and allow the tropical cyclones to recurve. Later, as the tropical cyclones approached the Philippine Islands, southwestward movement was observed due to surges in the northeast monsoon, which had fully established itself across the Philippine Islands and South China Sea. During wintertime synoptic regimes, forecast difficulties were also compounded by the instability of the One-Way Interactive Tropical Cyclone Model (OTCM), JTWC's primary dynamic forecast aid, due to kinetic energy conversion problems.

Tables 3-1 through 3-6 provide information on the monthly and annual distribution of tropical cyclones, warnings and tropical cyclone formation alerts.

TABLE 3-1. WESTERN NORTH PACIFIC 1986 SIGNIFICANT TROPICAL CYCLONES

TROPICAL CYCLONE	PERIOD OF WARNING	CALENDAR DAYS OF WARNING	NUMBER OF WARNINGS ISSUED	MAXIMUM SURFACE WINDS-KT (M/S)	ESTIMATED MSLP - MB
01W TY JUDY	01 FEB - 06 FEB	5	21	85 (44)	974
02W TY KEN	26 APR - 01 MAY	5	18	90 (46)	980
03W STY LOLA	17 MAY - 23 MAY	7	26	150 (77)	910
04W TS MAC	26 MAY - 29 MAY	4	15	45 (23)	992
05W TY NANCY	21 JUN - 25 JUN	4	15	80 (41)	955
06W TS OWEN	28 JUN - 02 JUL	5	17	50 (26)	987
07W STY PEGGY	03 JUL - 11 JUL	9	35	140 (72)	900
08W TY ROGER	13 JUL - 17 JUL	5	19	85 (44)	955
09W TS SARAH	30 JUL - 04 AUG	6	22	55 (28)	986
11E TY GEORGETTE	09 AUG - 15 AUG	7	26	65 (33)	973
10W TY TIP	13 AUG - 19 AUG	7	25	80 (41)	965
11W TS VERA #1	15 AUG - 17 AUG	3	7	40 (21)	995
11W TY VERA #2	17 AUG - 29 AUG	13	48	110 (57)	923
12W TY WAYNE	18 AUG - 25 AUG	8	29	85 (44)	956
12W TY WAYNE*	28 AUG - 06 SEP	10	38	90 (46)	951
13W TY ABBY	13 SEP - 20 SEP	8	30	95 (49)	943
14W TY BEN	19 SEP - 30 SEP	12	46	120 (62)	917
15W TY CARMEN	02 OCT - 08 OCT	7	27	100 (51)	939
16W TS DOM	09 OCT - 11 OCT	3	11	45 (23)	990
17W TY ELLEN	11 OCT - 19 OCT	8	33	80 (41)	970
18W TY FORREST	15 OCT - 20 OCT	6	19	110 (57)	932
19W TS GEORGIA	18 OCT - 21 OCT	4	15	55 (28)	983
20W TS HERBERT	08 NOV - 11 NOV	4	16	60 (31)	986
21W TS IDA	10 NOV - 16 NOV	6	22	55 (28)	986
22W TY JOE	18 NOV - 24 NOV	7	24	100 (51)	940
23W STY KIM	28 NOV - 11 DEC	13	52	140 (72)	905
24W TS LEX	03 DEC - 05 DEC	3	8	40 (21)	994
25W TY MARGE	14 DEC - 23 DEC	10	38	95 (49)	947
26W TY NORRIS	21 DEC - 01 JAN	11	43	90 (46)	953
	1986 TOTALS:	163 **	743 ***		

* REGENERATED

** OVERLAPPING DAYS INCLUDED ONLY ONCE IN SUM.

*** YEAR-END TOTAL DOES NOT INCLUDE TWO WARNINGS ON TY NORRIS ON 01 JAN 87.

NOTE: DISTANCE TRAVELED HAS NOT BEEN PROVIDED, BUT CAN BE COMPUTED FROM RAW DATA - SEE ANNEX A.

TABLE 3-2

WESTERN NORTH PACIFIC TROPICAL CYCLONE DISTRIBUTION

Year	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTALS
1959	0	1	1	1	0	1	3	8	9	3	2	2	31
	000	010	010	100	000	001	111	512	423	210	200	200	17 7 7
1960	1	0	1	1	1	3	3	9	5	4	1	1	30
	001	000	001	100	010	210	210	810	041	400	100	100	19 8 3
1961	1	1	1	1	4	6	5	7	6	7	2	1	42
	010	010	100	010	211	114	320	313	510	322	101	100	20 11 11
1962	0	1	0	1	3	0	8	8	7	5	4	2	39
	000	010	000	100	201	000	512	701	313	311	301	020	24 6 9
1963	0	0	1	1	0	4	5	4	4	6	0	3	28
	000	000	001	100	000	310	311	301	220	510	000	210	19 6 3
1964	0	0	0	0	3	2	8	8	8	7	6	2	44
	000	000	000	000	201	200	611	350	521	331	420	101	26 13 5
1965	2	2	1	1	2	4	6	7	9	3	2	1	40
	110	020	010	100	101	310	411	322	531	201	110	010	21 13 6
1966	0	0	0	1	2	1	4	9	10	4	5	2	38
	000	000	000	100	200	100	310	531	532	112	122	101	20 10 8
1967	1	0	2	1	1	1	8	10	8	4	4	1	41
	010	000	110	100	010	100	332	343	530	211	400	010	20 15 6
1968	0	1	0	1	0	4	3	8	4	6	4	0	31
	000	001	000	100	000	202	120	341	400	510	400	000	20 7 4
1969	1	0	1	1	0	0	3	3	6	5	2	1	23
	100	000	010	100	000	000	210	210	204	410	110	010	13 6 4
1970	0	1	0	0	0	2	3	7	4	6	4	0	27
	000	100	000	000	000	110	021	421	220	321	130	000	12 12 3
1971	1	0	1	2	5	2	8	5	7	4	2	0	37
	010	000	010	200	230	200	620	311	511	310	110	000	24 11 2
1972	1	0	1	0	0	4	5	5	6	5	2	3	32
	100	000	001	000	000	220	410	320	411	410	200	210	22 8 2
1973	0	0	0	0	0	0	7	6	3	4	3	0	23
	000	000	000	000	000	000	430	231	201	400	030	000	12 9 2
1974	1	0	1	1	1	4	5	7	5	4	4	2	35
	010	000	010	010	100	121	230	232	320	400	220	020	15 17 3
1975	1	0	0	1	0	0	1	6	5	6	3	2	25
	100	000	000	001	000	000	010	411	410	321	210	002	14 6 5
1976	1	1	0	2	2	2	4	4	5	0	2	2	25
	100	010	000	110	200	200	220	130	410	000	110	020	14 11 0
1977	0	0	1	0	1	1	4	2	5	4	2	1	21
	000	000	010	000	001	010	301	020	230	310	200	100	11 8 2
1978	1	0	0	1	0	3	4	8	4	7	4	0	32
	010	000	000	100	000	030	310	341	310	412	121	000	15 13 4
1979	1	0	1	1	2	0	5	4	6	3	2	3	28
	100	000	100	100	011	000	221	202	330	210	110	111	14 9 5
1980	0	0	1	1	4	1	5	3	7	4	1	1	28
	000	000	001	010	220	010	311	201	511	220	100	010	15 9 4
1981	0	0	1	1	1	2	5	8	4	2	3	2	29
	000	000	100	010	010	200	230	251	400	110	210	200	16 12 1
1982	0	0	3	0	1	3	4	5	6	4	1	1	28
	000	000	210	000	100	120	220	500	321	301	100	100	19 7 2
1983	0	0	0	0	0	1	3	6	3	5	5	2	25
	000	000	000	000	000	010	300	231	111	320	320	020	12 11 2
1984	0	0	0	0	0	2	5	7	4	8	3	1	30
	000	000	000	000	000	020	410	232	130	521	300	100	16 11 3
1985	2	0	0	0	1	3	1	7	5	5	1	2	27
	020	000	000	000	100	201	100	520	320	410	010	110	17 9 1
1986	0	1	0	1	2	2	2	5	2	5	4	3	27
	000	100	000	100	110	110	200	410	200	320	220	210	19 8 0
(1959-1986) AVG	0.5	0.3	0.6	0.8	1.3	2.1	4.6	6.3	5.6	4.6	2.8	1.5	30.9
CASES	15	9	18	21	36	58	128	175	157	130	78	41	866

Legend: Total for the month —— $\boxed{6}$

Typhoons —— $\boxed{3}$ $\boxed{1}$ $\boxed{2}$
Tropical Storms
Tropical Depressions

NOTE: This new compilation of 1959 through 1986 data was done after establishing a standard for the times when a tropical cyclone existed in two separate months. The criterion used follows:

1. If a tropical cyclone was first warned on during the last two days of a particular month and continued over into the next month for longer than two days, then that system was attributed to the second month.
2. If a tropical cyclone was warned on prior to the last two days of a month, it was attributed to the first month - no matter how long the system lasted.
3. If a tropical cyclone began on the last day of the month and ended on the first day of the next month, that tropical cyclone was attributed to the first month. However, if a tropical cyclone began on the last day of the month and continued into the next month for two days only, then it was attributed to the second month.

TABLE 3-3

WESTERN NORTH PACIFIC SUMMARY

TYPHOONS

(1945-1958)

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTALS
AVG	0.4	0.1	0.3	0.4	0.7	1.1	2.0	2.9	3.2	2.4	2.0	0.9	16.3
CASES	5	1	4	5	10	15	28	41	45	34	28	12	228

(1959-1986)

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTALS
AVG	0.2	0.1	0.2	0.5	0.7	1.0	2.7	3.3	3.3	3.0	1.7	0.7	17.4
CASES	6	2	6	15	19	29	76	91	91	85	47	19	486

TROPICAL STORMS AND TYPHOONS

(1945-1958)

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTALS
AVG	0.4	0.1	0.4	0.5	0.8	1.6	3.0	3.9	4.1	3.3	2.8	1.1	22.0
CASES	6	1	6	7	11	22	42	54	58	46	39	16	308

(1959-1986)

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTALS
AVG	0.5	0.3	0.5	0.7	1.1	1.8	4.1	5.3	4.9	4.1	2.6	1.3	27.1
CASES	14	8	14	20	30	49	116	147	136	116	73	36	759

(1986)

FORMATION ALERTS: 27 of 38 Formation Alerts developed into significant tropical cyclones. Tropical Cyclone Formation Alerts were issued for all of the significant tropical cyclones that developed in 1986.

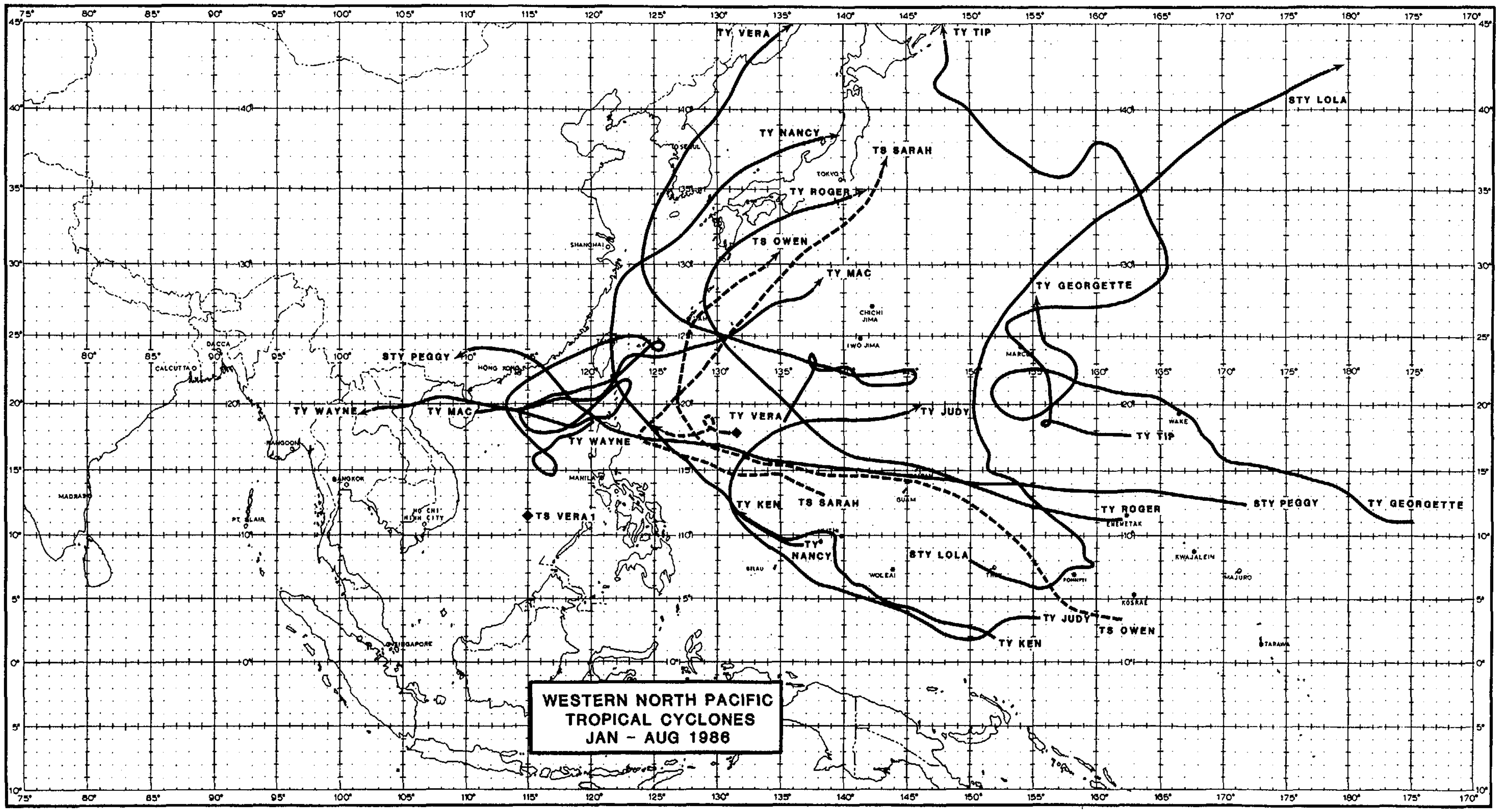
WARNINGS:

Number of calendar warning days:	163
Number of calendar warning days with two tropical cyclones:	32
Number of calendar warning days with three tropical cyclones:	4

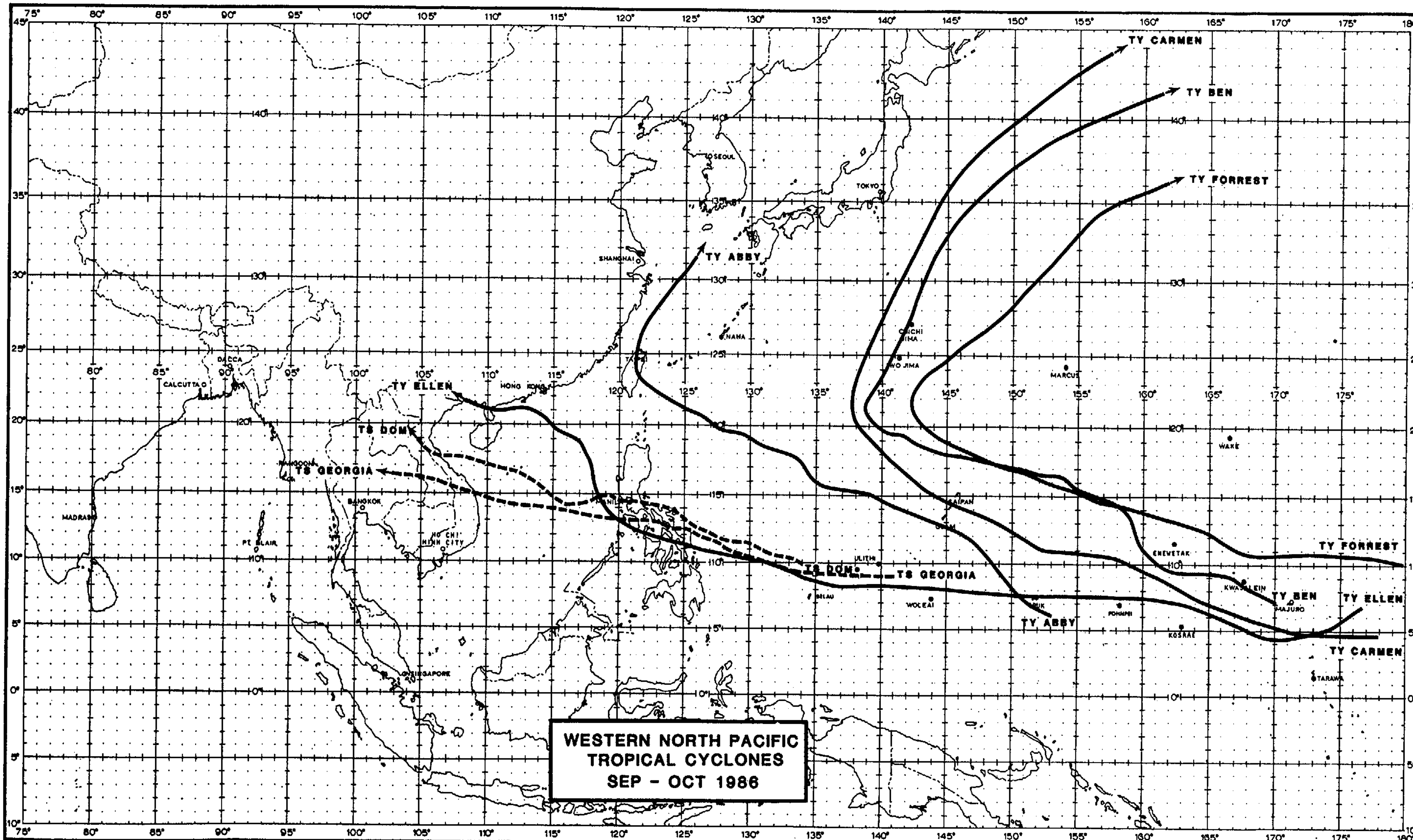
TABLE 3-4.

FORMATION ALERT SUMMARY WESTERN NORTH PACIFIC

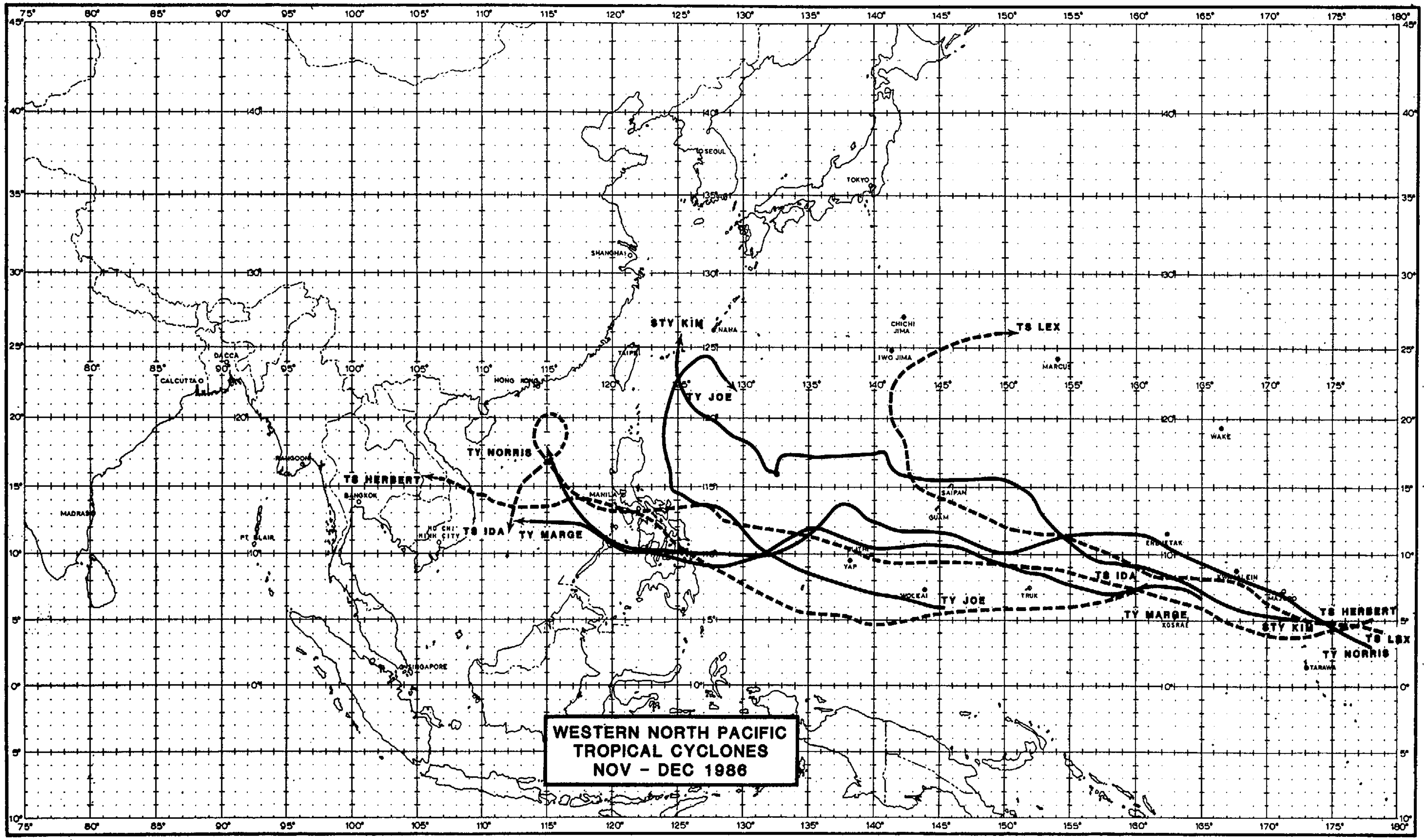
YEAR	NUMBER OF ALERT SYSTEMS	ALERT SYSTEMS WHICH BECAME NUMBERED TROPICAL CYCLONES	TOTAL NUMBERED TROPICAL CYCLONES	FALSE ALARM RATE
1975	34	25	25	26%
1976	34	25	25	26%
1977	26	20	21	23%
1978	32	27	32	16%
1979	27	23	28	15%
1980	37	28	28	24%
1981	29	28	29	3%
1982	36	26	28	28%
1983	31	25	25	19%
1984	37	30	30	19%
1985	39	26	27	33%
1986	38	27	27	29%
(1975-1986) AVERAGE	33.3	25.8	27.1	21.9%
CASES	400	310	325	



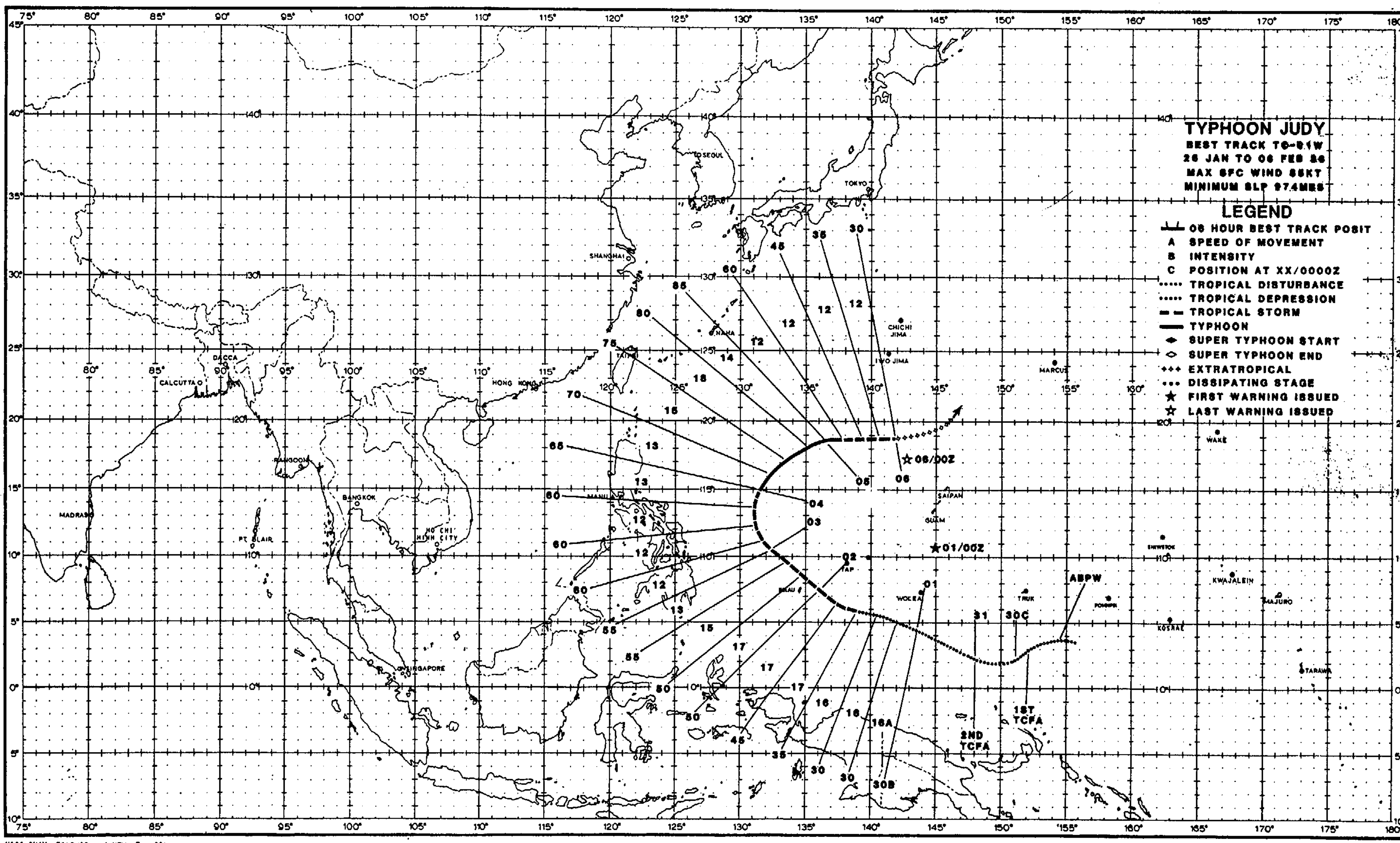
NOCC GUAM 3142/20 (NEW 5 - 80)



NOCC GUAM 3142/20 (NEW 5 - 80)



NOCC GUAM 3142/20 (NEW 5 - 80)



NOCC GUAM 3142/20 (NEW 5 - 80)

The formation of Typhoon Judy marked the start of the western North Pacific tropical cyclones for 1986. Judy originated near two degrees North Latitude in the near-equatorial trough. It was aided in its initial development by brisk northeasterly trade flow associated with a shear line situated to the north and the low latitude monsoonal westerlies in the southern hemisphere. Judy was also the season's first tropical cyclone to enter the mid-latitude westerlies and recurve.

During most of January, a winter weather pattern dominated the tropical western North Pacific area. Convective activity was confined to low latitudes on the periphery of the near-equatorial trough (NET). In the last week of January, the NET extended from the southern Philippines east-southeast to the equator 420 nm (778 km) south-southeast of the island of Pohnpei.

The cloud system first appeared late on 25 January as an area of disorganized convection 300 nm (556 km) in diameter. With unrestricted upper-level outflow to the north and west, the convection persisted through the diurnal minimum period (around 0400Z) on the 26th and was first noted on the Significant Tropical Weather Advisory (ABPW PGTW) at 260600Z.

During the next three days, the convection continued a gradual increase in areal extent, but remained poorly organized. Early on 29 January, an aircraft reconnaissance investigative mission flown into the disturbance was unable to locate a low-level circulation center. However, the Aerial Reconnaissance Weather Officer (ARWO) estimated a minimum sea-level pressure (MSLP) in the area at 1001 mb. Since this pressure was approximately 6 mb below the surrounding environmental MSLP to the north and the disturbance was expected to track westward into an upper-level environment with less vertical wind shear, a Tropical Cyclone Formation Alert (TCFA) was issued at 290630Z.

A second investigative mission flown early on the 30th also failed to locate a definite low-level circulation. The ARWO estimated maximum surface winds of 25 kt (13 m/sec) to 35 kt (18 m/sec) to the north in the easterly flow. Satellite imagery and synoptic data indicated this enhanced flow was a result of a shear line to the north of the disturbed area. Because of a decrease in both convection (diurnal) and low-level inflow, the TCFA for the disturbance was cancelled at 300600Z.

Post analysis indicates this cancellation was premature. Satellite imagery, over the next forty-eight hours, detected a dramatic increase in convection associated with this slowly, westward moving disturbance. Analysis of satellite imagery (Figure 3-01-1) prompted the issuance of a second

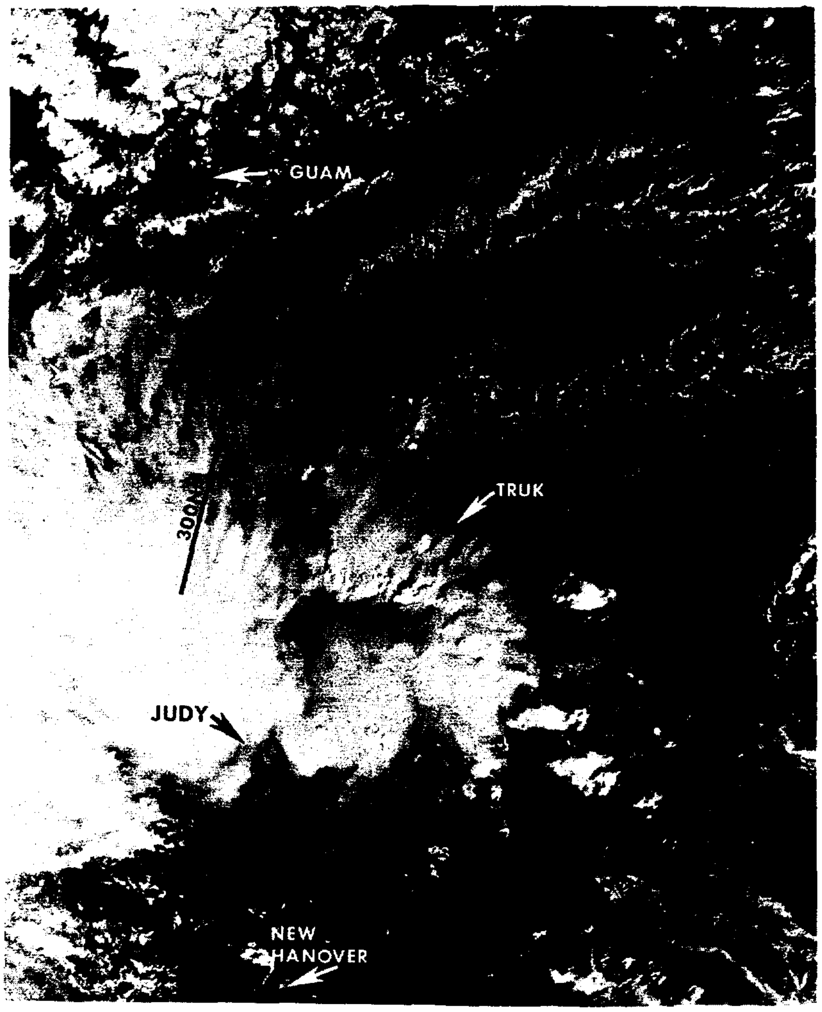


Figure 3-01-1. Judy just prior to issuance of second TCFA (302349Z January DMSP visual imagery).

TCFA at 310130Z. Twenty-four hours later, infrared satellite imagery indicated a upper-level anticyclone was developing over the disturbance and (Dvorak) satellite intensity analysis estimated surface winds of 30 kt (15 m/sec). This prompted the initial warning at 010000Z on Judy, as a 30 kt (15 m/sec) tropical depression. Within twenty-four hours, Judy was upgraded to tropical storm intensity based on the aircraft reconnaissance data.

The initial forecasts called for Judy to track west-northwestward. Due to the uncertainty of the position of the ridge axis and its strength over the data sparse Philippine Sea, 400 mb synoptic tracks were flown on the 2nd and 3rd of February to help define the mid-level flow north of Judy. Data from these flights confirmed the presence of the east-west orientation of the ridge axis and indicated a weakness in the ridge along 130 degrees East Longitude with strong westerly mid-level flow north of 16 degrees North Latitude. With the above information and mindful of a similar synoptic pattern associated with Typhoon Hope in December 1985, JTWC altered the forecast to reflect initial northward movement followed by recurvature toward the northeast. As with Typhoon Hope (1985), Judy was expected to undergo a rapid extratropical transition with a drastic decrease in intensity and no significant eastward movement. The dynamic forecast guidance proved of no assistance in this regard apparently due to the strongly sheared/baroclinic environment.

Judy slowed slightly as it approached the ridge near 131 degrees East Longitude early on 3 February. Continuing to intensify, the system tracked north briefly before turning northeast. Judy reached its maximum intensity of 85 kt (44 m/s) with a MSLP of 974 mb at 050000Z (see Figure 3-01-2). As it reached maximum intensity, Judy also came under the influence of strong mid-latitude westerlies. By 060000Z, Judy's convection had been sheared away and extratropical transition was complete. The nearly convective free low-level circulation drifted slowly east-northeast and dissipated. No deaths, injuries or property damage were attributed to Typhoon Judy.

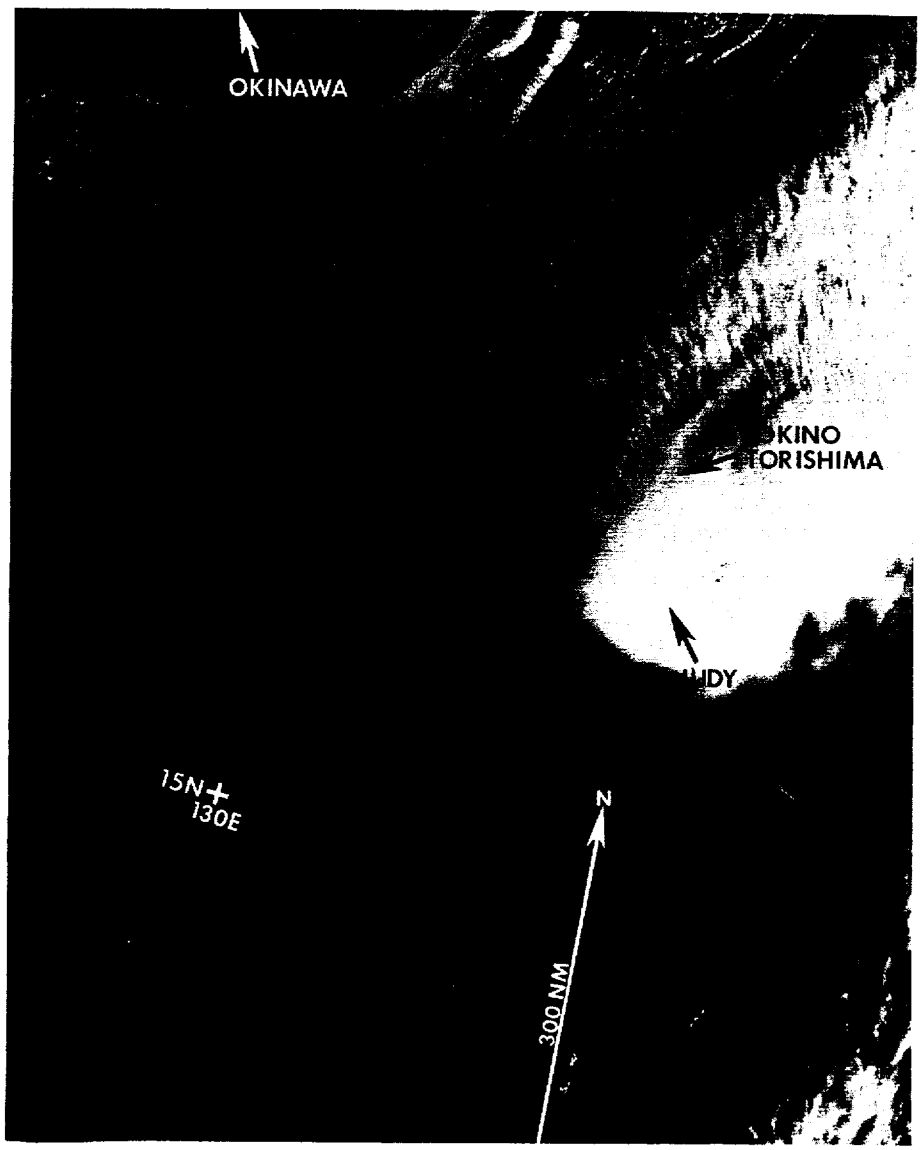
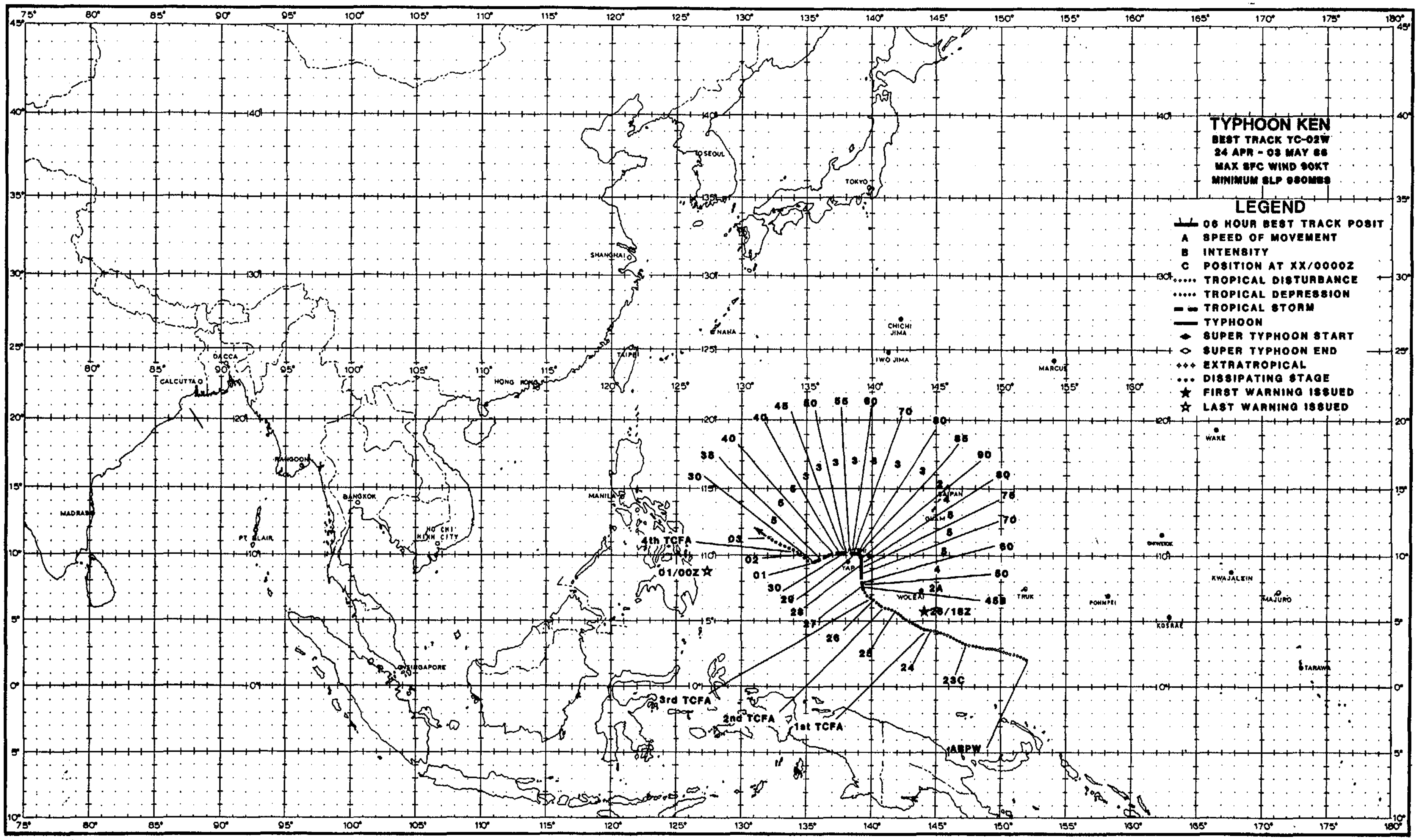


Figure 3-01-2. Typhoon Judy near maximum intensity (050120Z February DMSP visual imagery).



NOCC GUAM 3142/20 (NEW 5 - 80)

Typhoon Ken, the second tropical cyclone of 1986, was also the first tropical cyclone to develop in the western North Pacific in April during the past five years. After the formation of Ken, two tropical systems quickly followed in May.

During late April, the near-equatorial trough was quite active with enhanced convective activity from the southern Philippine Islands to the region south of Truk near the equator. Embedded within this trough was the tropical disturbance that eventually intensified into Typhoon Ken. At 200600Z, it was mentioned on the Significant Tropical Weather Advisory (ABPW PGTW) for the first time. No surface circulation was present, only convergent flow at the low levels. Synoptic data on 21 April indicated a weak surface circulation 540 nm (1000 km) south of Guam. The associated convection increased in amount and organization through the 23rd. Analysis of satellite imagery showed continued development and winds were estimated at 20 kt (10 m/sec). As a result, JTWC issued a Tropical Cyclone Formation Alert (TCFA) at 240730Z.

The first aircraft reconnaissance investigative mission was conducted the following day. It located a weak circulation center at 5000 ft (1524 m) 250 nm (463 km) southeast of Yap. Estimated surface winds were 10 to 25 kt (5 to 13 m/sec). These data, plus satellite imagery, prompted JTWC to reissue the TCFA at 250730Z.

A second aircraft reconnaissance investigative mission was conducted on the morning of the 26th and was again unable to locate a surface circulation. Instead, a broad area of troughing was observed at the surface with the maximum low-level winds of 25 to 30 kt (13 to 15 m/sec) within the convection banding in the northeast quadrant of the disturbance. Satellite data indicated the upper-level circulation center existed 90 nm (167 km) to the east-southeast of Yap (Figure 3-02-1). Based on that information, the third TCFA was issued at 260730Z.

The first warning on Ken was issued at 261900Z after satellite imagery showed a significant increase in the central convection and the development of a comma-shaped cloud pattern. Surface winds were

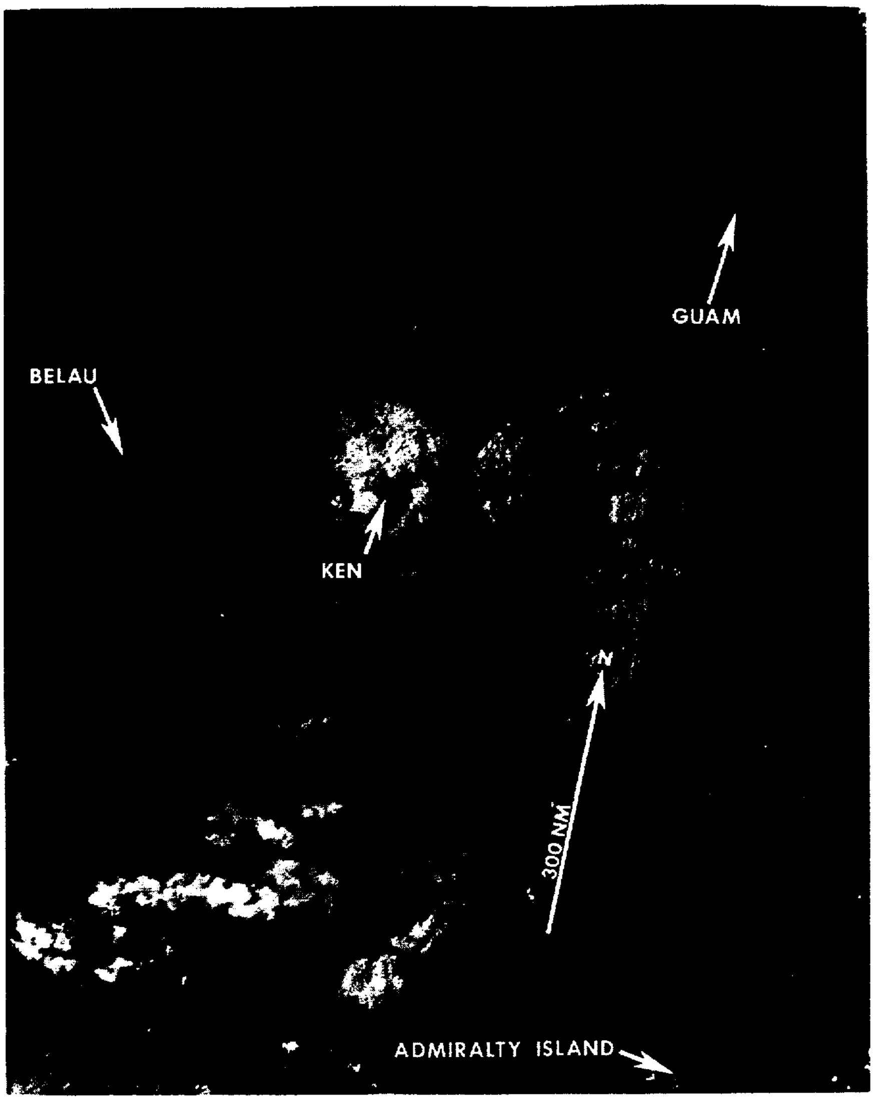


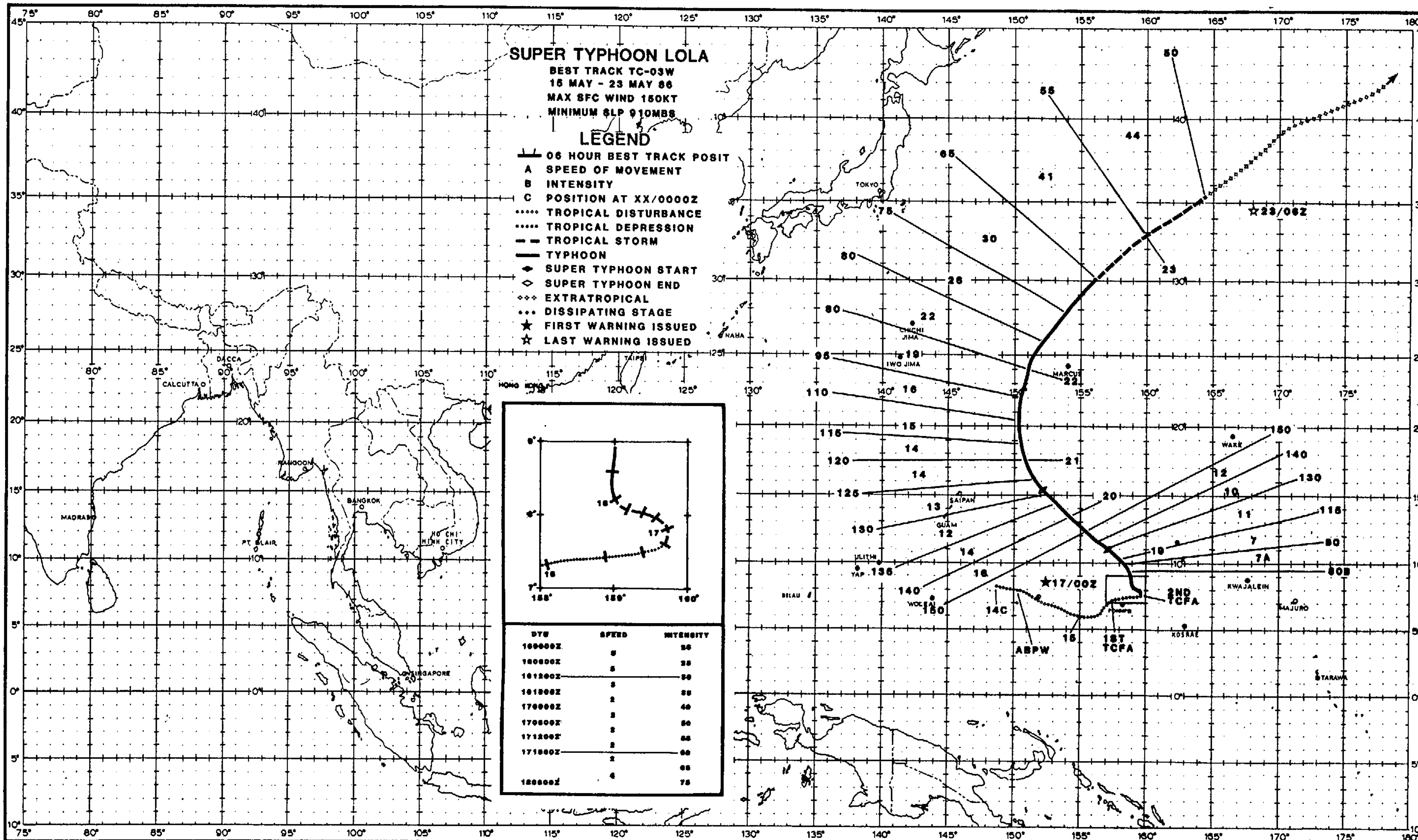
Figure 3-02-1. Typhoon Ken at the time the third TCFA was issued. The aircraft reconnaissance investigative mission into the disturbance two hours earlier was unable to find a surface circulation (260500Z April NOAA visual imagery).

estimated at 35 kt (18 m/sec). Ken reached typhoon intensity on the 27th. Aircraft reconnaissance penetration of the system revealed a compact surface circulation, a minimum sea-level pressure (MSLP) of 980 mb, and an elliptical eye (oriented east-west). Peripheral aircraft data showed the stronger surface winds of 30 to 50 kt (15 to 26 m/sec) in the northern semicircle in contrast to 15 to 20 kt (8 to 10 m/sec) in the southern semicircle. This resulted from the higher pressure gradient between Ken's low pressure center and the subtropical ridge. As gradual intensification took place, the forecast track for Ken became more northerly based on the expected influence of the mid-latitude trough on the mid-level subtropical ridge and the general tendency of intensifying tropical cyclones to move into higher latitudes. By 281800Z, after the trough passed eastward from Japan, the subtropical ridge reintensified across the northern Philippine Sea, forcing Ken to move westward.

Ken's intensity peaked at 90 kt (46 m/sec) on the 28th. Satellite imagery showed the system remained compact with a slight east-west elongation of the central dense overcast and an eye which was obscured by high cirrus. On the 29th, Ken began to weaken significantly. Aircraft reconnaissance reports indicated that the 700 mb center was displaced 20 nm (37 km) northeast of the surface center due to increased shearing flow aloft from the southwest. Throughout the next day, both aircraft and satellite reconnaissance found an exposed low-level circulation center. Since the upper-level circulation center was now displaced 170 nm (315 km) to the northeast of the low-level circulation (Figure 3-02-2), the last warning, valid at 0300Z on the first of May, was issued. Stripped of its deep central convection, the residual low-level cyclonic vorticity drifted westward and dissipated over water by the 3rd.

No reports of damage or injuries were attributed to Ken. Of interest, Ken's proximity to Guam and slow movement caused official concern because of the scheduled refueling stop of Air Force One at Andersen AFB. Once the tropical cyclone's track changed to west late on 28 April, serious worries were removed. In summary, forecasting direction changes for slow moving tropical cyclones is usually difficult - Ken was no exception. JTWC's ability to correctly forecast slow movement along the track resulted in a good product and excellent statistics.

Figure 3-02-2. Typhoon Ken during its final stage. Note the large (170 nm (315 km)) displacement between the exposed low-level circulation and the upper-level circulation (302133Z April DMSP visual imagery).


SUPER TYPHOON LOLA
BEST TRACK TC-03W
15 MAY - 23 MAY 86
MAX SFC WIND 150KT
MINIMUM SLP 910MBS
LEGEND
06 HOUR BEST TRACK POSIT
A SPEED OF MOVEMENT
B INTENSITY
C POSITION AT XX/0000Z
TROPICAL DISTURBANCE
TROPICAL DEPRESSION
TROPICAL STORM
TYPHOON
SUPER TYPHOON START
SUPER TYPHOON END
EXTRATROPICAL
DISSIPATING STAGE
FIRST WARNING ISSUED
LAST WARNING ISSUED
★17/00Z
☆23/06Z
2ND TCFA
1ST TCFA
ABPW
DTG
SPEED
INTENSITY
TOKYO
NAHA
TAIPEI
HONG KONG
CHICHI JIMA
IWO JIMA
MARCUS
SAIPAN
GUAM
ULITHI
YAP
WOLEAI
PONAPE
KOSRAE
KWAJALEIN
MAJURO
TARAWA
WAKE
DACCA
CALCUTTA
RANGOON
BANGKOK
MADRAS
PT BLAIR
HO CHI MINH CITY
SINGAPORE

Super Typhoon Lola was the first of three super typhoons (tropical cyclones with 130 kt (67 m/sec) or greater intensity) to occur during 1986. Lola's appearance coincided with a very destructive tropical cyclone in the southern hemisphere, Tropical Cyclone 33P (Namu) (see Figure 3-03-1). Namu, an unusual "twin" cyclone with Lola, was the worst tropical cyclone to strike the Solomon Islands this century. Over 90,000 people were left homeless on the island of Guadalcanal and nearly 100 people died as a result of the fury of Namu. From a historical perspective, Lola was of particular interest to residents of Guam since its appearance coincided with the ten year anniversary of Super Typhoon Pamela's devastating visit to the island on May 21, 1976. Super Typhoon Pamela (1976) destroyed 40 percent of the homes on Guam and caused extensive damage with torrential rains and maximum sustained winds of 120 kt (63 m/sec) and gusts to 145 kt (70 m/sec).

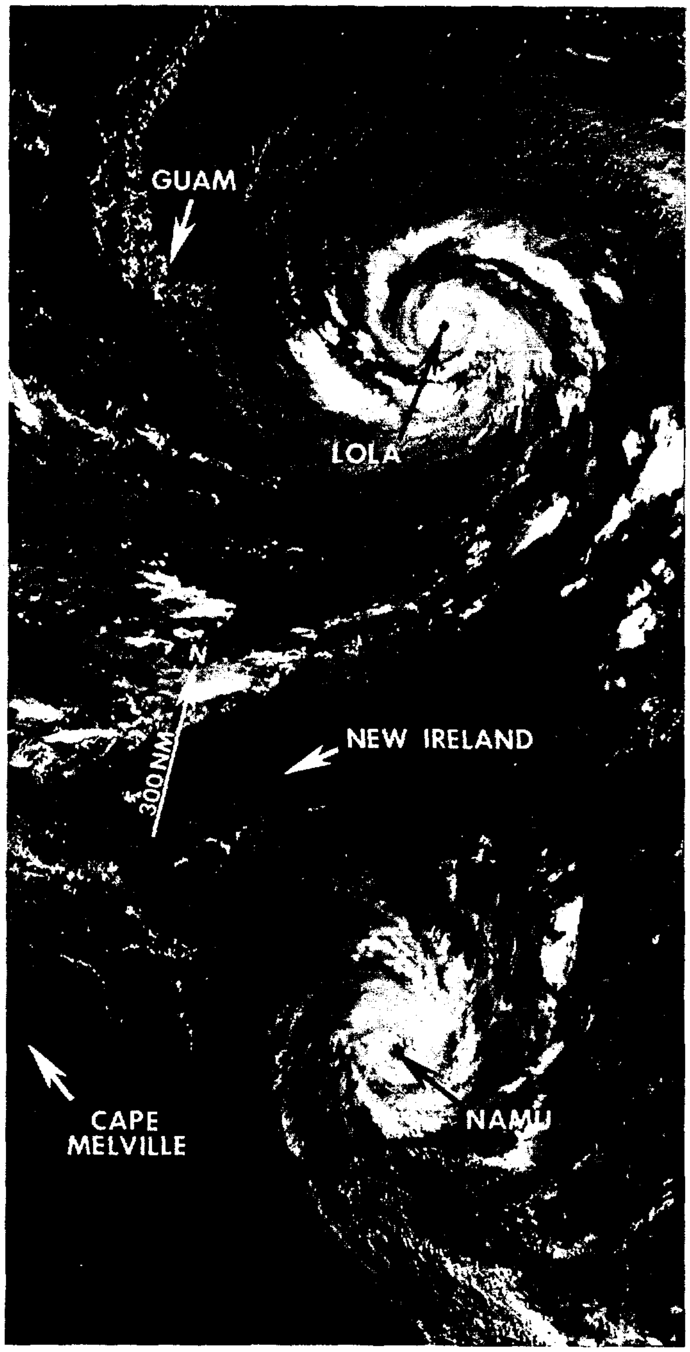


Figure 3-03-1. Super Typhoon Lola and Tropical Cyclone 33P (Namu). This is an unusual case of "twin" tropical cyclones occurring in opposite hemispheres (192349Z May DMSP visual imagery).

Lola began as a tropical disturbance in a very active monsoon trough extending from south of Guam eastward to the Marshall Islands. This area of disturbed weather was enhanced by two opposing wind flows - cross-equatorial winds provided strong southwesterly flow and the tradewinds provided northeasterly flow. For several days prior to Lola's inception, destructive winds and torrential rains battered the Caroline Islands. The island atoll of Nukuoro 285 nm (528 km) southeast of Truk, for example, experienced damage from winds of 40 kt (21 m/sec) with gusts to 60 kt (31 m/sec) on 14 May associated with severe thunderstorms.

At that time Lola was just a tropical disturbance 50 nm (93 km) northwest of Truk and received mention on the Significant Tropical Weather Advisory (ABPW PGTW) because of its persistent cloudiness. Within 24-hours, sea-level pressures dropped throughout the monsoon trough as Lola increased in organization (see Figure 3-03-2). These

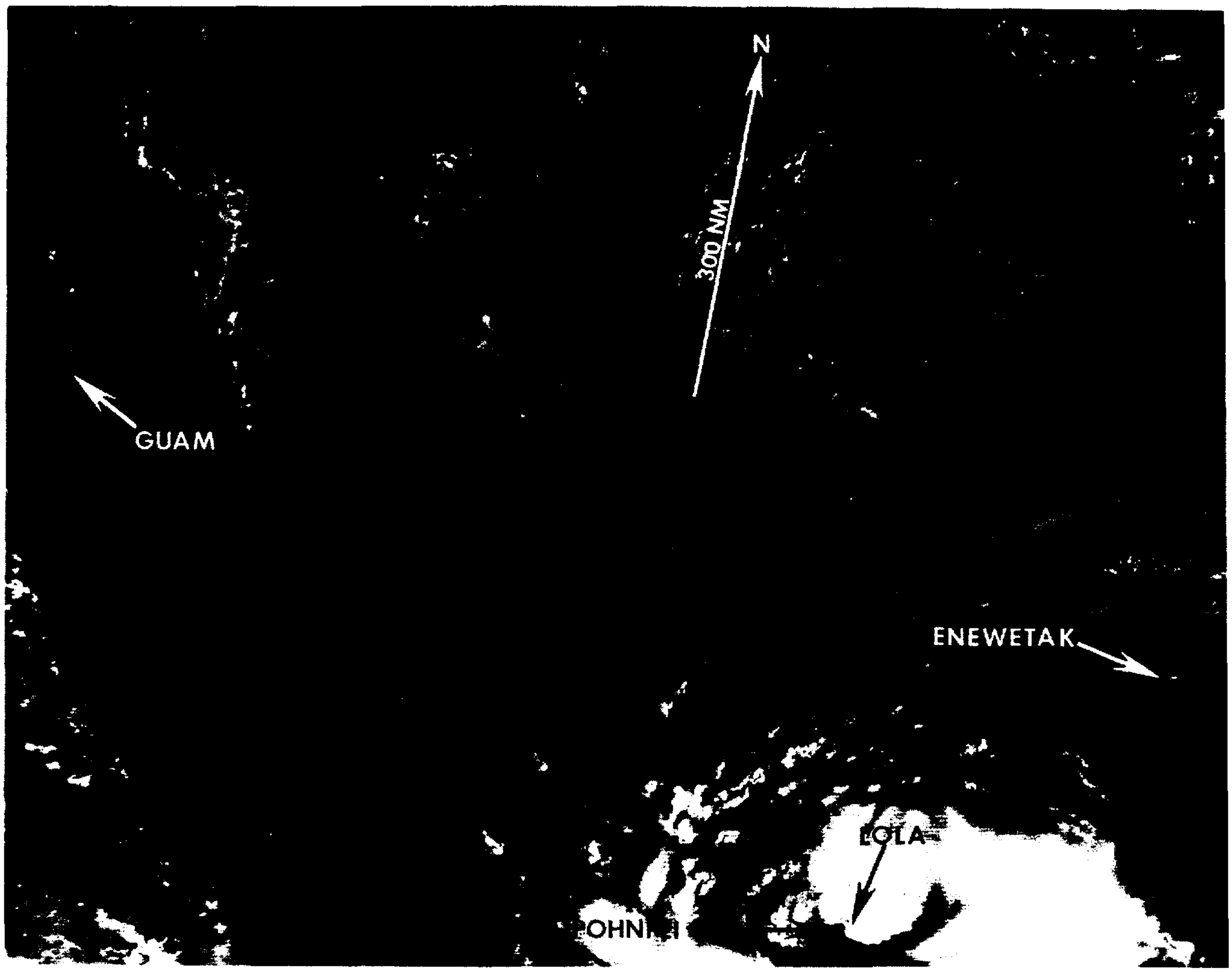


Figure 3-03-2. Lola showing increased organization at low latitudes (152330Z May DMSP visual imagery).

events prompted the issuance of a Tropical Cyclone Formation Alert (TCFA) valid at 152330Z. Aircraft reconnaissance scheduled to investigate the disturbance at that time turned back to Guam due to the loss of hydraulic fluid. A second TCFA was issued at 161530Z when Lola moved outside of the alert area. The first warning on Tropical Depression 03W followed at 170000Z based on analysis of satellite imagery (Figure 3-03-3) and synoptic data that clearly indicated a closed circulation. An aerial reconnaissance investigative mission later that day discovered winds of 40 kt (21 m/sec) at the surface and an estimated minimum sea-level pressure (MSLP) of 981 mb. Lola was subsequently upgraded to a tropical storm with the second warning, valid at 170600Z. Due to its proximity to Pohnpei, Lola caused extensive damage to the island; mostly due to flooding and high winds. Authorities there claimed it was the worst battering Pohnpei had suffered in the past 28 years since Typhoon Ophelia (1958).

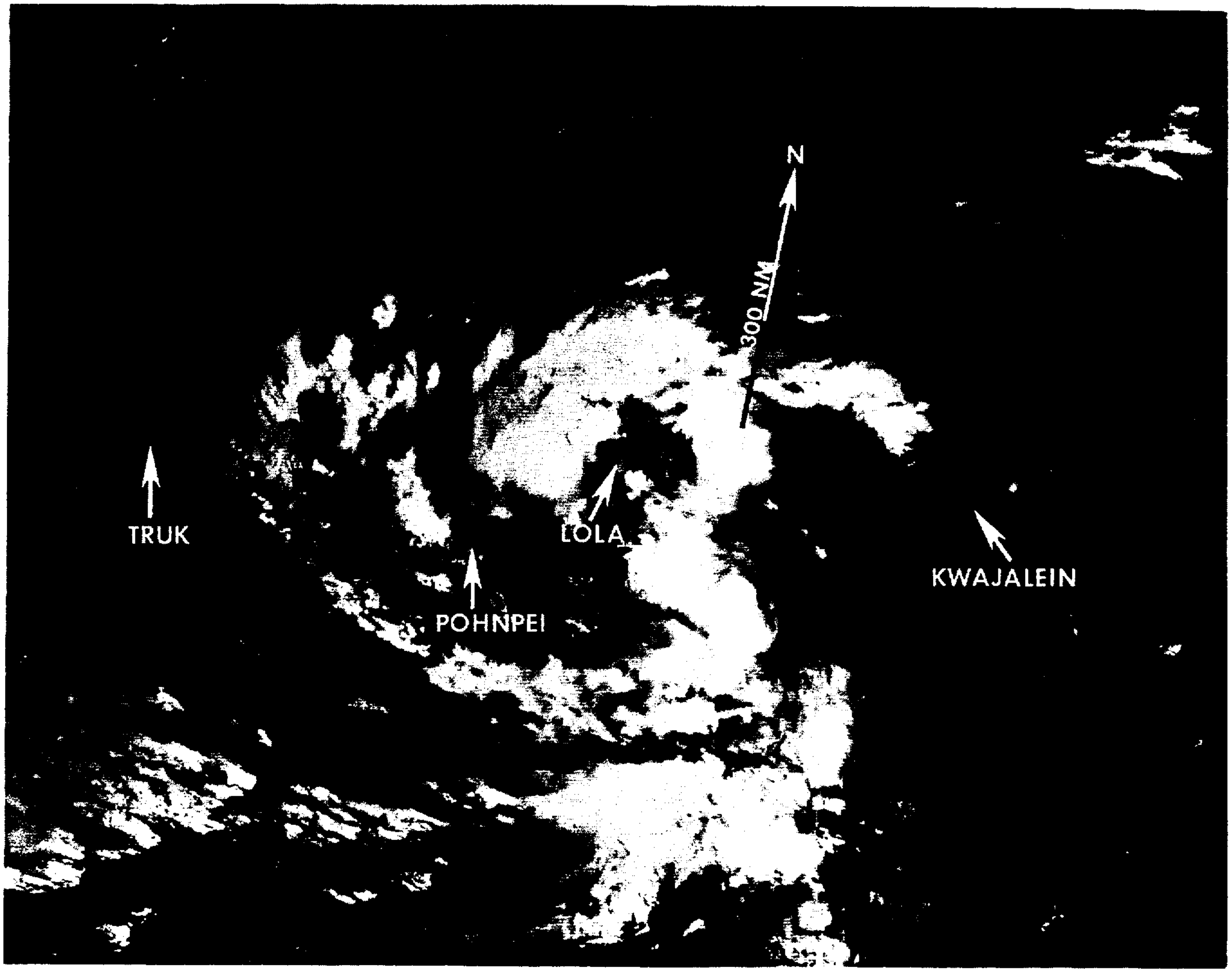


Figure 3-03-3. Lola a day later showing more convective activity and curvature (162309Z May DMSP visual imagery).

By early morning on the 18th, Lola was already at typhoon intensity (see Figure 3-03-4). Initial interpretation of data from the second synoptic track mission flown along 18 degrees North Latitude determined there were no obvious breaks in the ridge north of Lola (Figure 3-03-5), thus the forecast took Lola northward initially, and then westward under the ridge. (Upon closer inspection of the 500 mb data, there is cyclonic turning at the western portion of the track. This implies a weakness in the subtropical ridge slightly north of the track and near 150 degrees East Longitude.) By late afternoon, Lola's intensity had increased to 75 kt (40 m/sec) and an eye became clearly visible on satellite imagery. A third synoptic track, flown the next day (19 May), again along 18 degrees North Latitude, still did not find any breaks in the subtropical ridge and the forecast appeared to be right on track. However, Lola was only two days away and all of Guam worried that this might be a repeat of Super Typhoon Pamela (1976). JTWC's warning on the morning of the 19th indicated Lola would become a super typhoon (see Figure 3-03-6). A three fix mission was flown into Typhoon Lola that morning to determine the rate at which it was intensifying. The results confirmed the worst - explosive deepening.

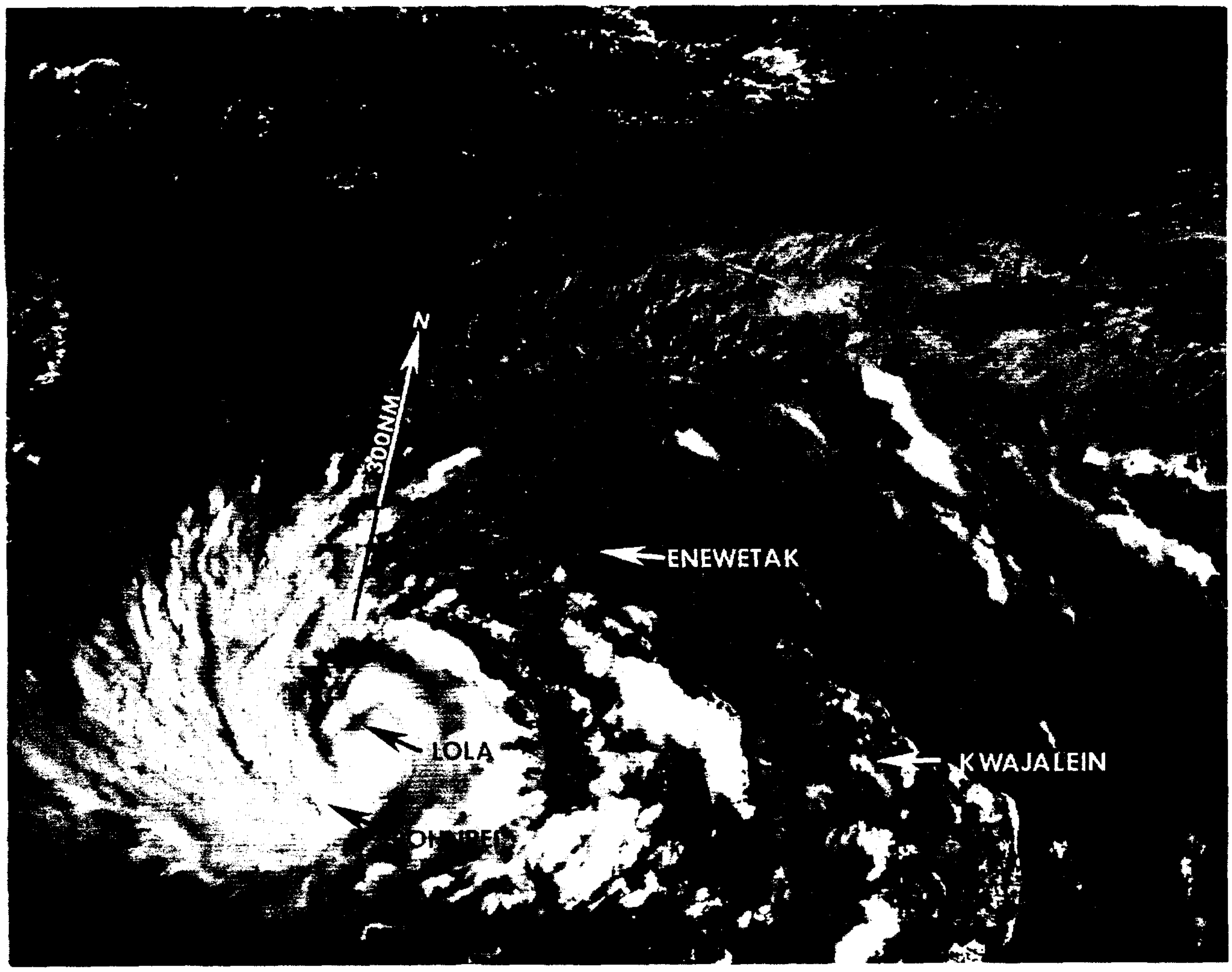


Figure 3-03-4. Lola on the third day reached typhoon intensity (172249Z May DMSP visual imagery).

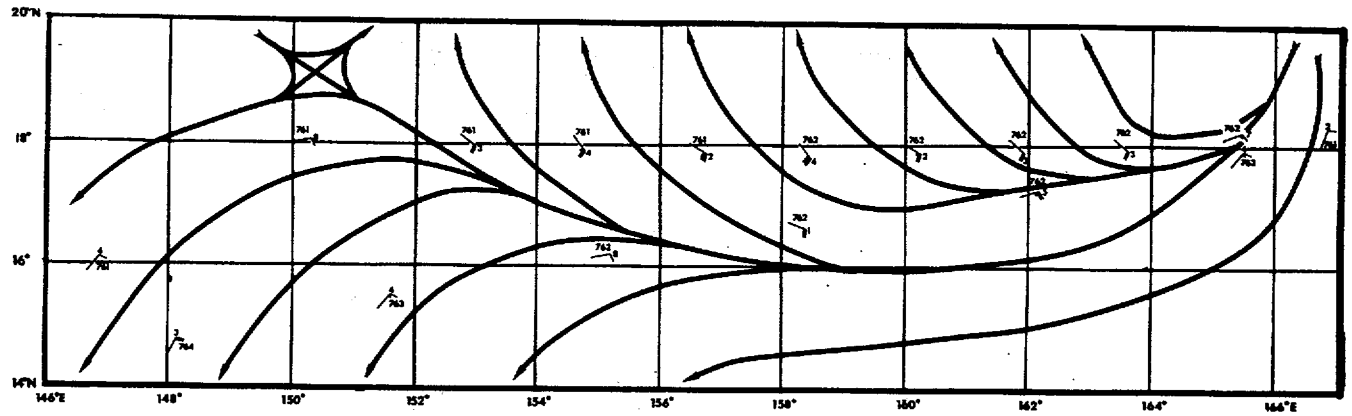


Figure 3-03-5. Data from the second synoptic track (172300Z through 180700Z) shows no obvious break in the subtropical ridge. (Upon closer inspection the streamlines imply a neutral point in the flow slightly north of the track and along 150 degrees East Longitude.)

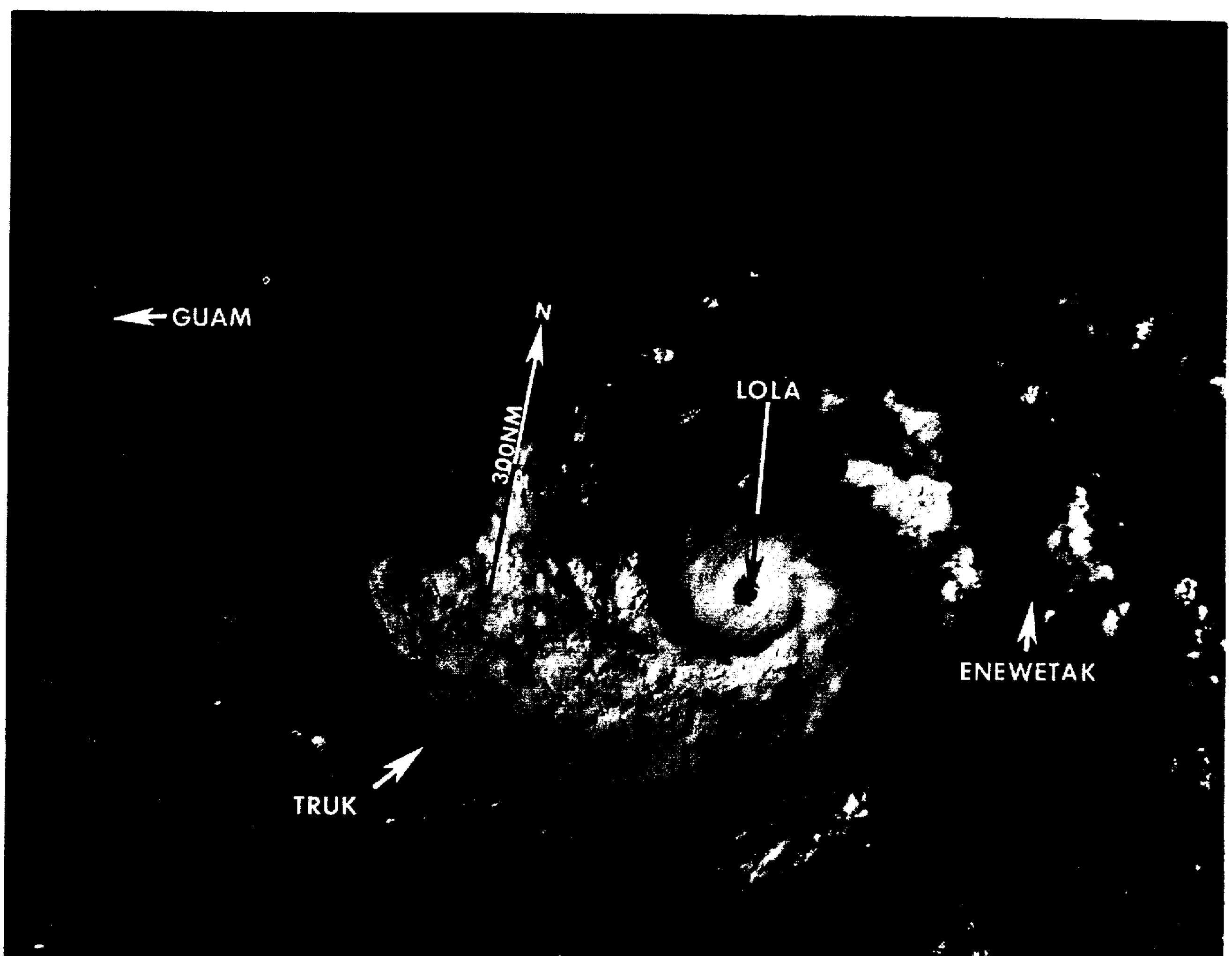


Figure 3-03-6. Lola near maximum intensity of 150 kt (77 m/sec) (190414Z May NOAA visual imagery).

Lola became a super typhoon at 130 kt (67 m/sec) and was forecast to intensify even more as it neared Guam. A fourth synoptic track mission was sent out on 20 May to locate any weakness in the subtropical ridge. The data showed the ridge at 400 mb displaced south and west across the path of Lola with a strong zone of mid-level divergence stretching from Guam through the northern Marianas (Figure 3-03-7). The forecast philosophy changed to a recurvature track rather than keeping the track toward the west-northwest. The intensity estimates indicated Lola had peaked at 191800Z at 150 kt (77 m/sec) and was now decreasing (see Figure 3-03-8). Aircraft reconnaissance that night (20 May) confirmed this

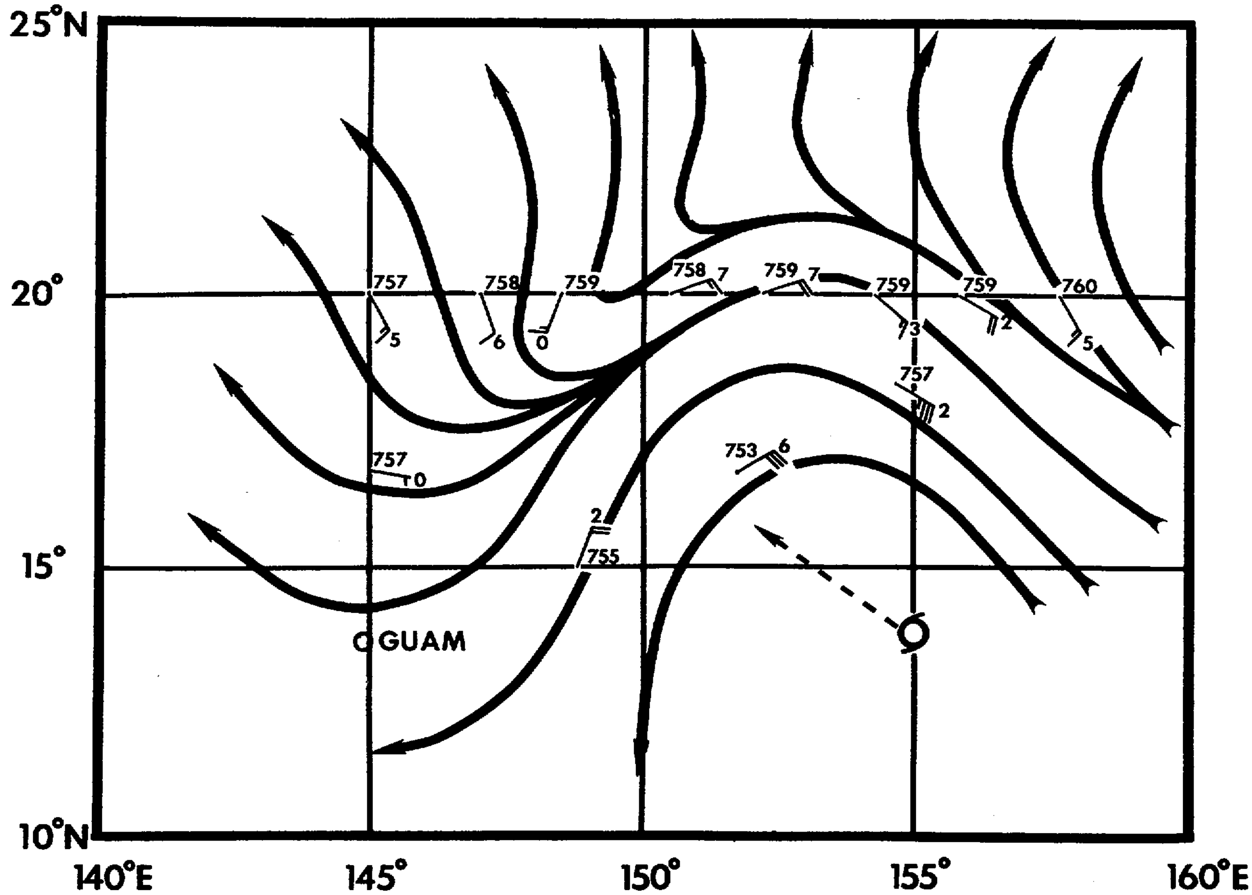


Figure 3-03-7. Data from the fourth synoptic track (192200Z through 200400Z May) shows the mid-level ridging displaced south and west across Guam.

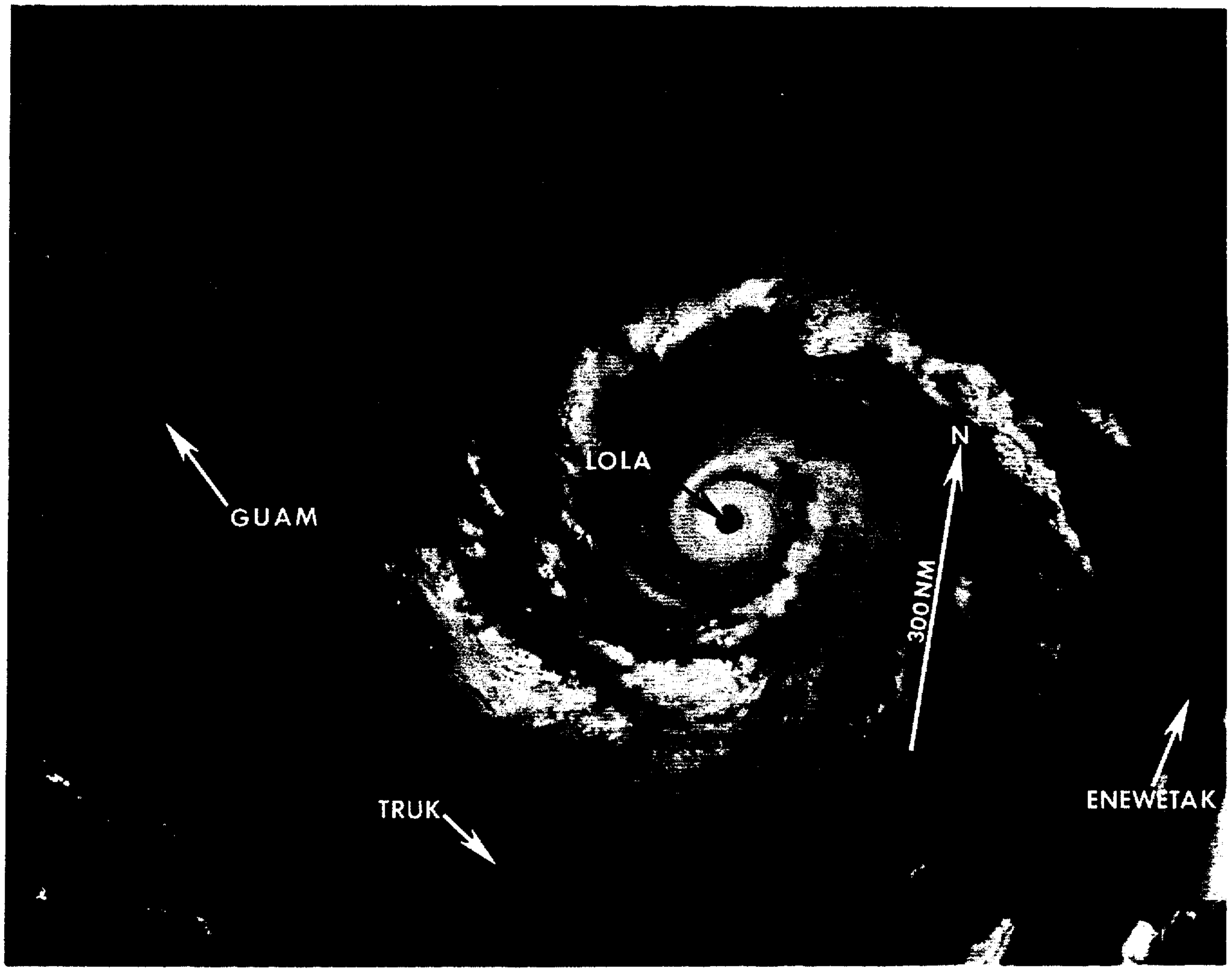


Figure 3-03-8. Lola shortly after it peaked at 150 kt (77 m/sec) (192350Z May DMSP visual imagery).

fact as the 700 mb heights also increased dramatically. Figures 3-03-9 and 3-03-10 show Lola weakening and becoming extratropical. Extratropical transition was completed on 23 May.

In retrospect, the early forecasts followed the Nested Tropical Cyclone Model (NTCM) too long during Lola's development and took the system toward the Marianas. Fortunately, JTWC made the right decision later to follow the One-way Interactive Tropical Cyclone Model (OTCM) and curved Lola toward the northeast before any major efforts had to be made to sortie ships and evacuate aircraft from the military bases on Guam (closest point of approach to Guam was 405 nm (750 km) to the northeast). However, the statistical damage had already been done and the overall forecast performance was only fair.

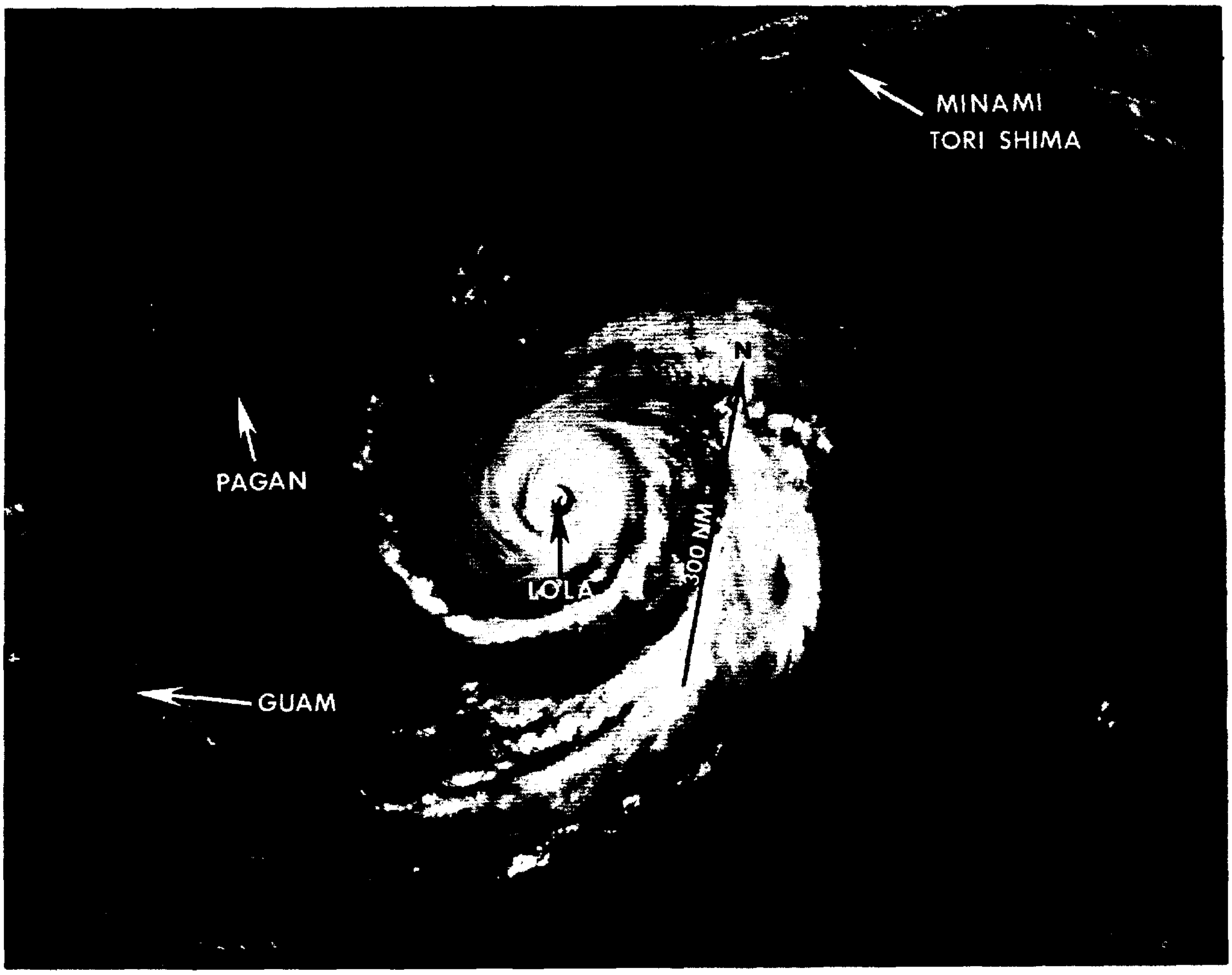


Figure 3-03-9. Lola decreasing in intensity (202329Z May DMSP visual imagery).

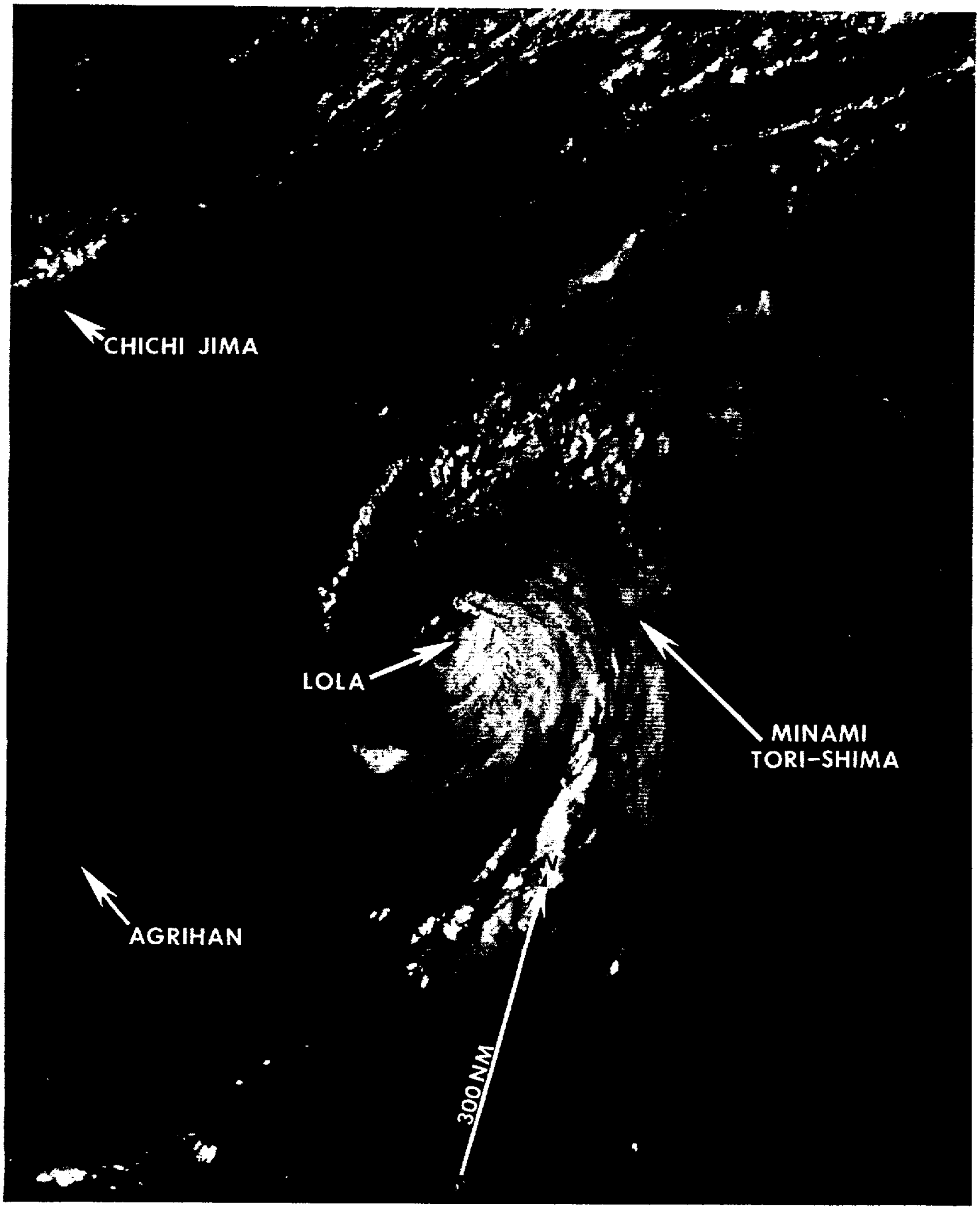
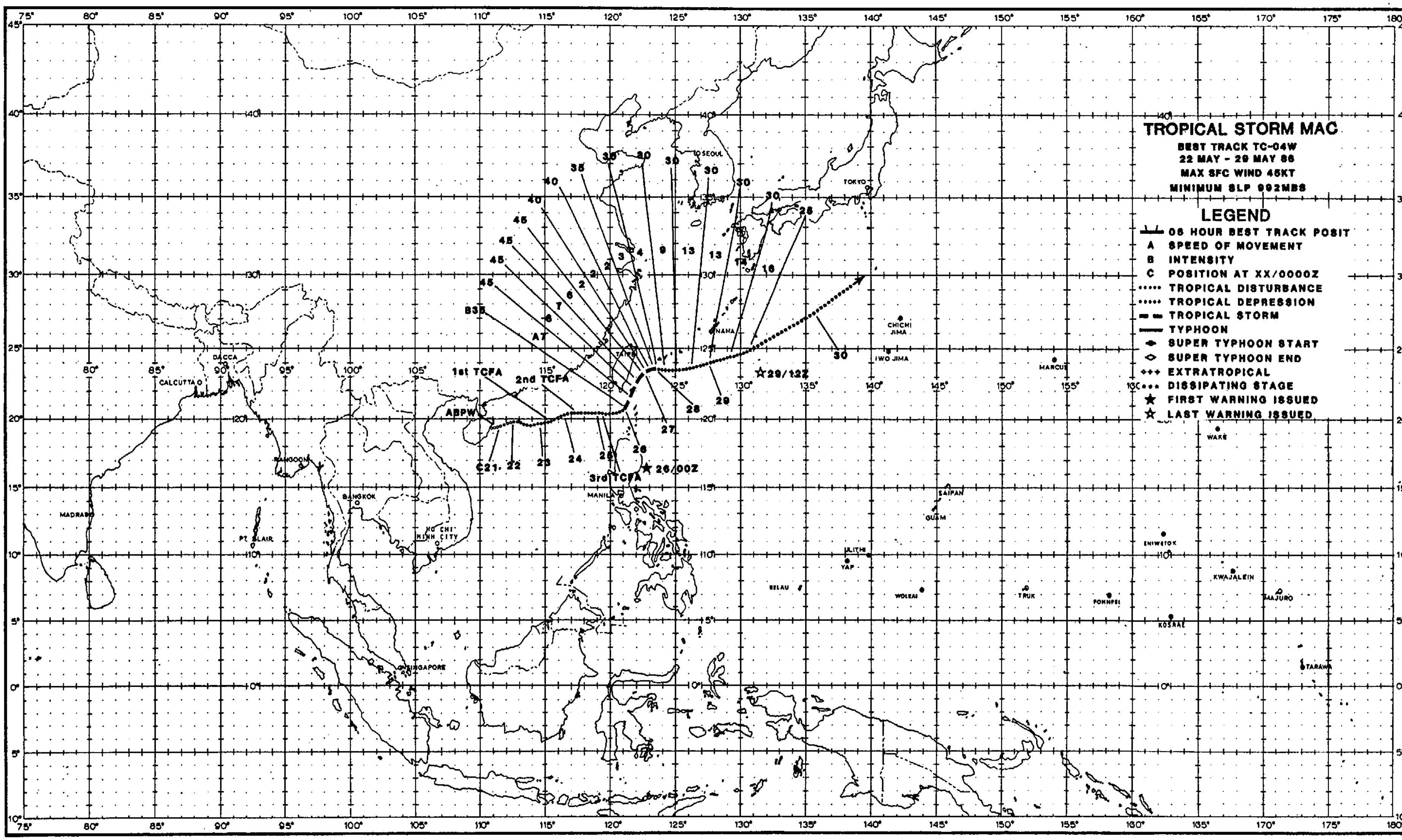


Figure 3-03-10. Lola transitioning to an extratropical system (212309Z May DMSP visual imagery).



NOCC GUAM 3142/20 (NEW 5 - 80)

Mac, from inception, was a "classic" monsoon depression - slow to develop, difficult to position and forecast. As Super Typhoon Lola (03W) was developing east of Guam, the precursor of Mac spawned in the monsoon trough in the South China Sea.

On May 20th, the Significant Tropical Weather Advisory (ABPW PGTW) mentioned a poorly defined area of convection in the monsoon trough, which was located over water and paralleled the southern coast of mainland China. Estimated maximum sustained surface winds of 20 kt (10 m/sec) and a minimum sea-level pressure (MSLP) of 998 mb were present. After several false starts, the organizing convection separated from the maximum cloudiness zone and a Tropical Cyclone Formation Alert was issued for the disturbance, at 230400Z, as it passed south of Hong Kong. The first warning was issued on Tropical Storm Mac (Figure 3-04-1) at 250000Z as development

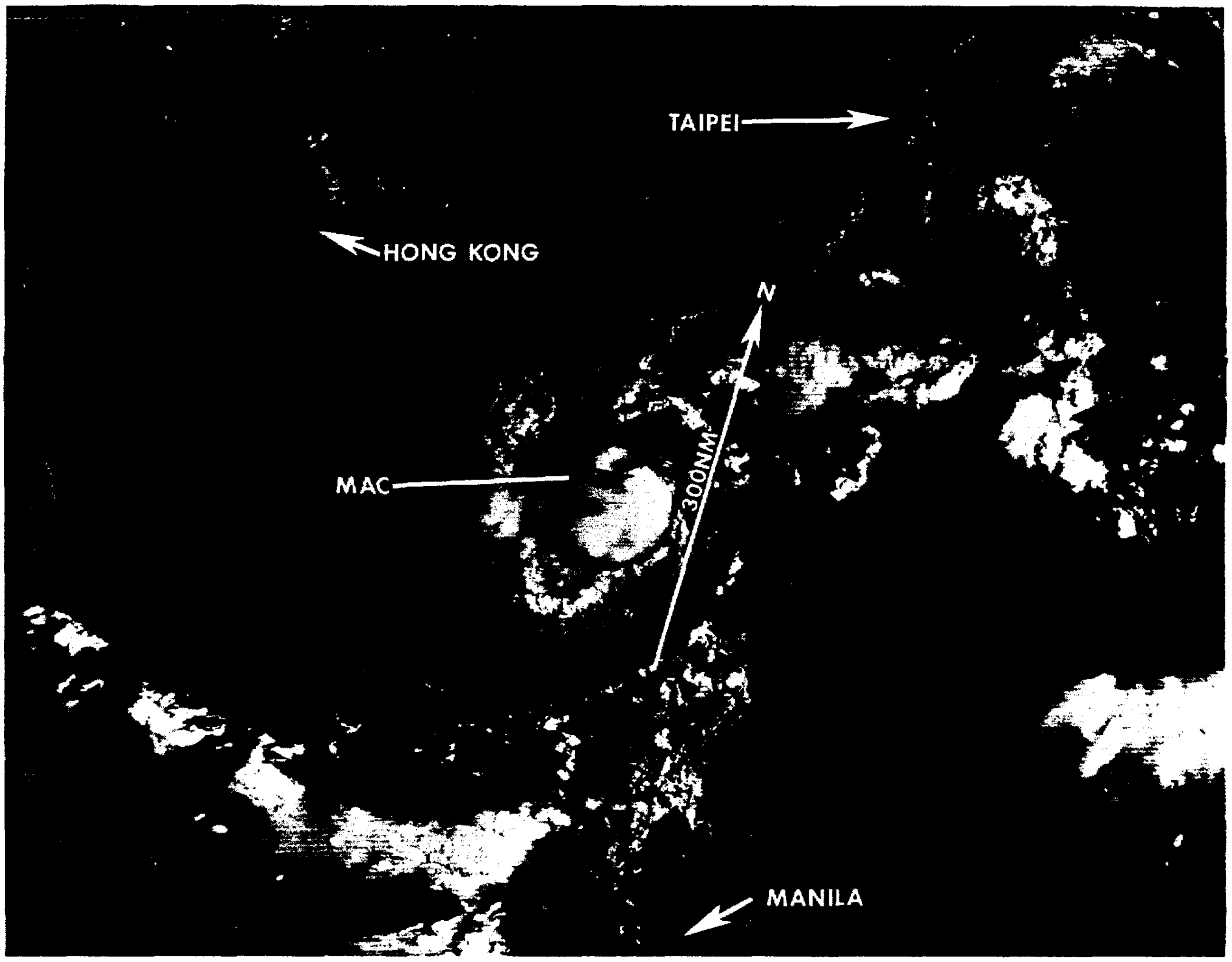


Figure 3-04-1. Tropical Depression 04W just an hour and a half after the first warning was issued (250131Z May DMSP visual imagery).

continued. Mac moved south of Taiwan and changed course toward the north-northeast as its intensity peaked at 45 kt (23 m/sec). At 270900Z, Mac appeared to become almost quasi-stationary. However, acceleration and an eastward movement commenced by 280600Z. Mac also weakened due to increased vertical shear and was, as a result, downgraded to a tropical depression on the 28th.

By May 29th, Mac's low-level circulation center was partially exposed (Figure 3-04-2). The last warning was issued at 291200Z as Mac began dissipating over water and redevelopment appeared less likely due to the persistent strong vertical wind shear.

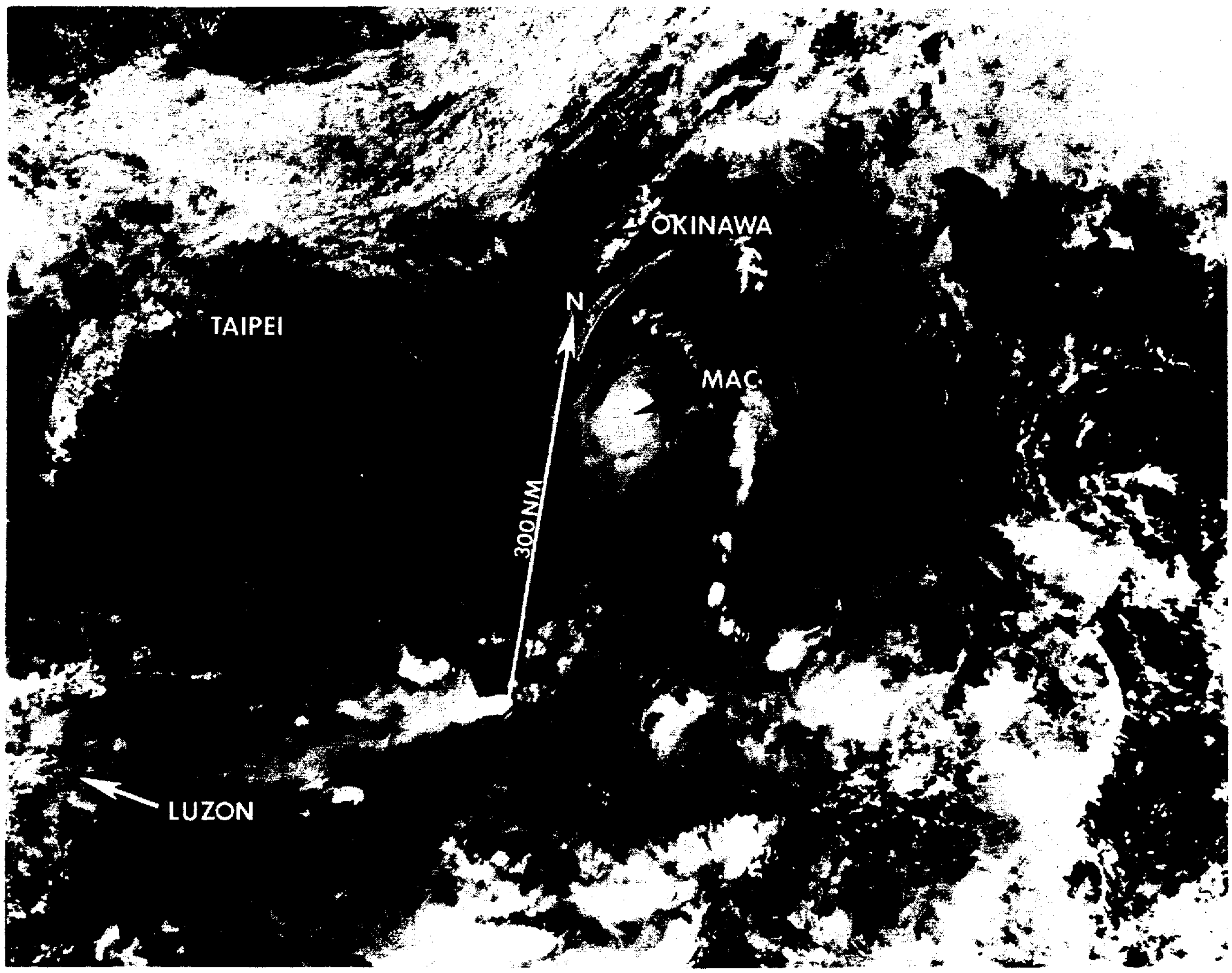
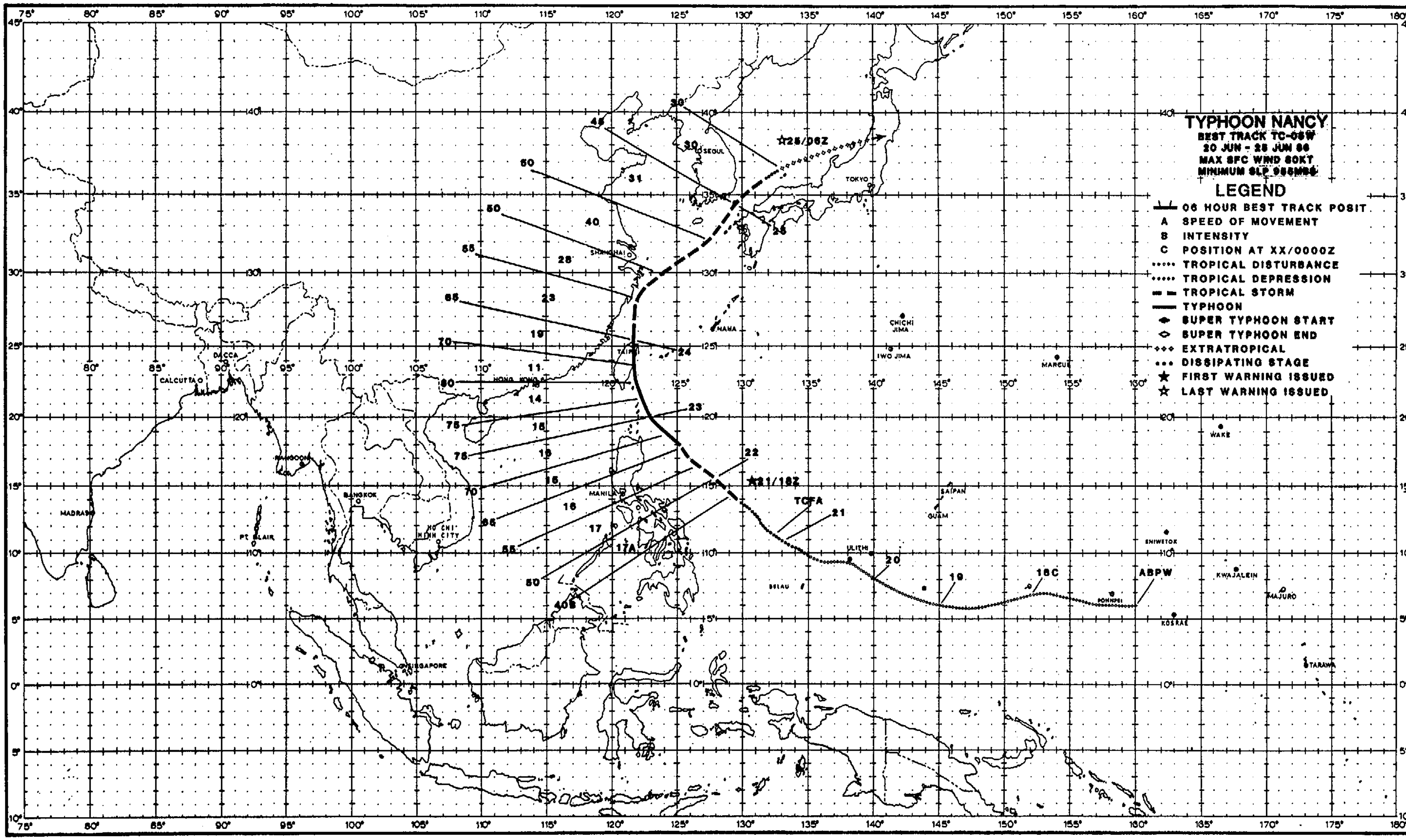


Figure 3-04-2. Mac's partially exposed low-level circulation center as seen six hours before the last warning was issued (290550Z May NOAA visual imagery).



NOCC GUAM 3142/20 (NEW 5 - 80)

For the first five months of 1986, the western North Pacific averaged less than one tropical cyclone per month. Nancy was the fifth tropical cyclone in the western North Pacific, but the first of the what is generally considered the summer typhoon season. After Typhoon Nancy, the summer season was in full swing.

The Significant Tropical Weather Advisory (ABPW PGTW) on 170600Z June mentioned an area of broad, disorganized convection which was developing 120 nm (222 km) southeast of Pohnpei. This area moved rapidly westward for the next two days, then slowed and began to consolidate. By 191200Z, an established cirrus outflow pattern, restricted to the northwest by an upper-level cold low 540 nm (1000 km) northwest of Guam, was detected on satellite imagery. Initial Dvorak intensity analysis of the cloud pattern estimated surface winds of less than 25 kt (13 m/sec). At 210330Z, a Tropical Cyclone Formation Alert (TCFA) was issued for the area. Within hours the convective curvature improved and the 211600Z Dvorak intensity estimate indicated winds of 30 kt (15 m/sec). Based on these data, the first warning for Tropical Depression 05W was issued at 211800Z.

Aircraft reconnaissance into Tropical Depression 05W at 220001Z reported maximum surface winds of 60 kt (31 m/sec) displaced 21 nm (39 km) east-southeast of the center of the system. Aircraft reconnaissance also observed a developing eyewall that was open on the west through north quadrants. As a result, the 220000Z warning upgraded Tropical Depression 05W to Tropical Storm Nancy. Less than 24-hours after the upgrading to tropical storm intensity, Nancy was upgraded to typhoon intensity. In retrospect, analyses of aircraft reconnaissance data and intensity trends indicate that tropical storm intensity was most probably attained at 211500Z, not 220000Z.

Throughout this period of development, Nancy (Figure 3-05-1) moved toward the northwest under the steering influence of the subtropical ridge to the north. Nearing the subtropical ridge axis on 23

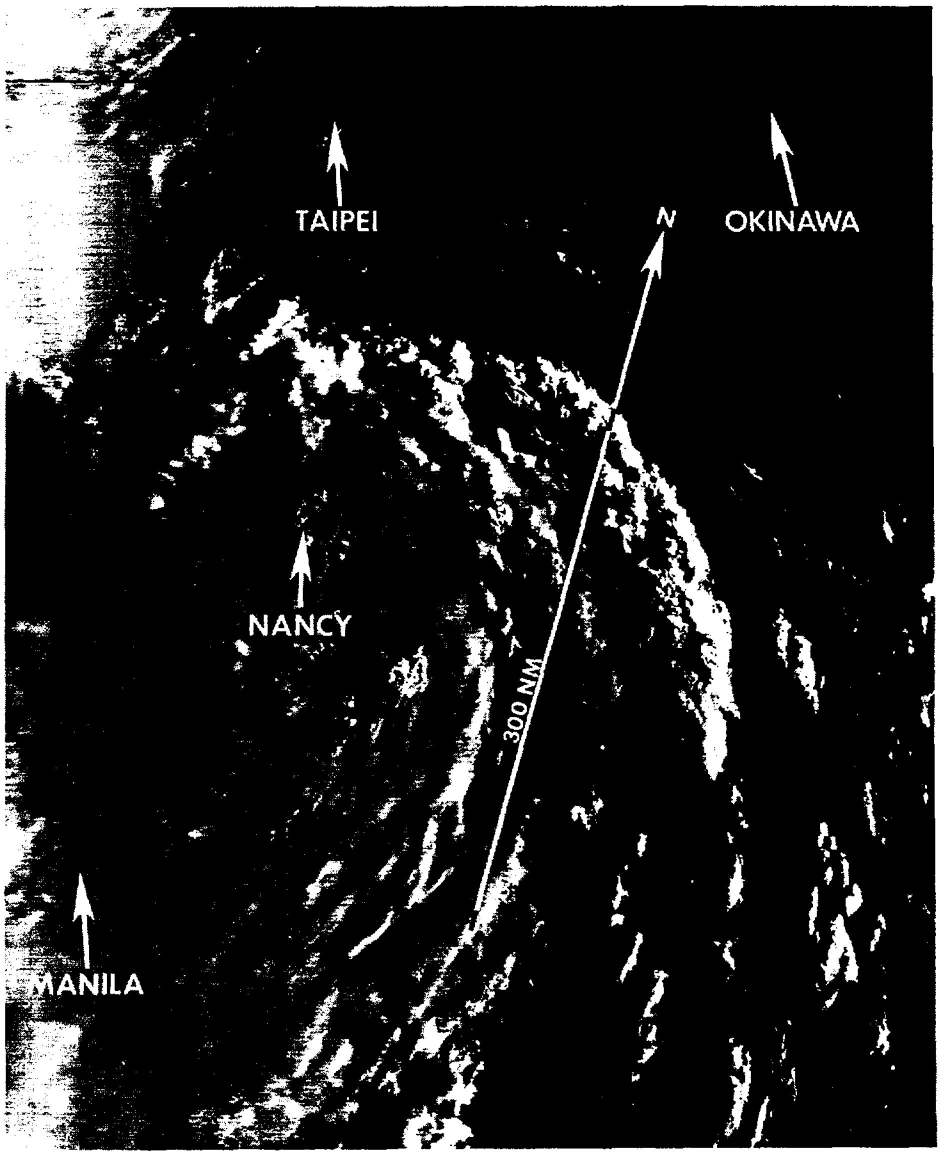


Figure 3-05-1. Typhoon Nancy approaching the island of Taiwan. The mountainous spine of the island is visible to the north of the tropical cyclone (222115Z June DMSP visual imagery).

June, the tropical cyclone assumed a more northerly course. For the next 24-hours aircraft reconnaissance data was unavailable due to the close proximity of land and airspace restrictions. Radar (Figure 3-05-2) and satellite (Figure 3-05-3) reports were particularly valuable during this time. These two figures, which were taken within one half hour of each other, provide strikingly different remotely sensed presentations of the eye. The radar detects the encircling rainbands, that are embedded in the clouds, and satellite sees the cold top of the central dense overcast as concentric patterns of gray shade. Just prior to making contact with the island of Taiwan, Nancy's intensity peaked at 80 kt (41 m/sec). The maximum surface wind reported from Taiwan was 63 kt (32 m/sec).

Continuing to move northward across the East China Sea, Nancy began interacting with a trough in the polar westerlies. The shape of the tropical cyclone became elongated as the low-level circulation center separated from the upper-level and the central convection decreased. At that time, Typhoon Nancy was downgraded to a tropical storm.

Later, aircraft reconnaissance at 242141Z was unable to locate a low-level circulation center due to airspace restrictions; however the peripheral data

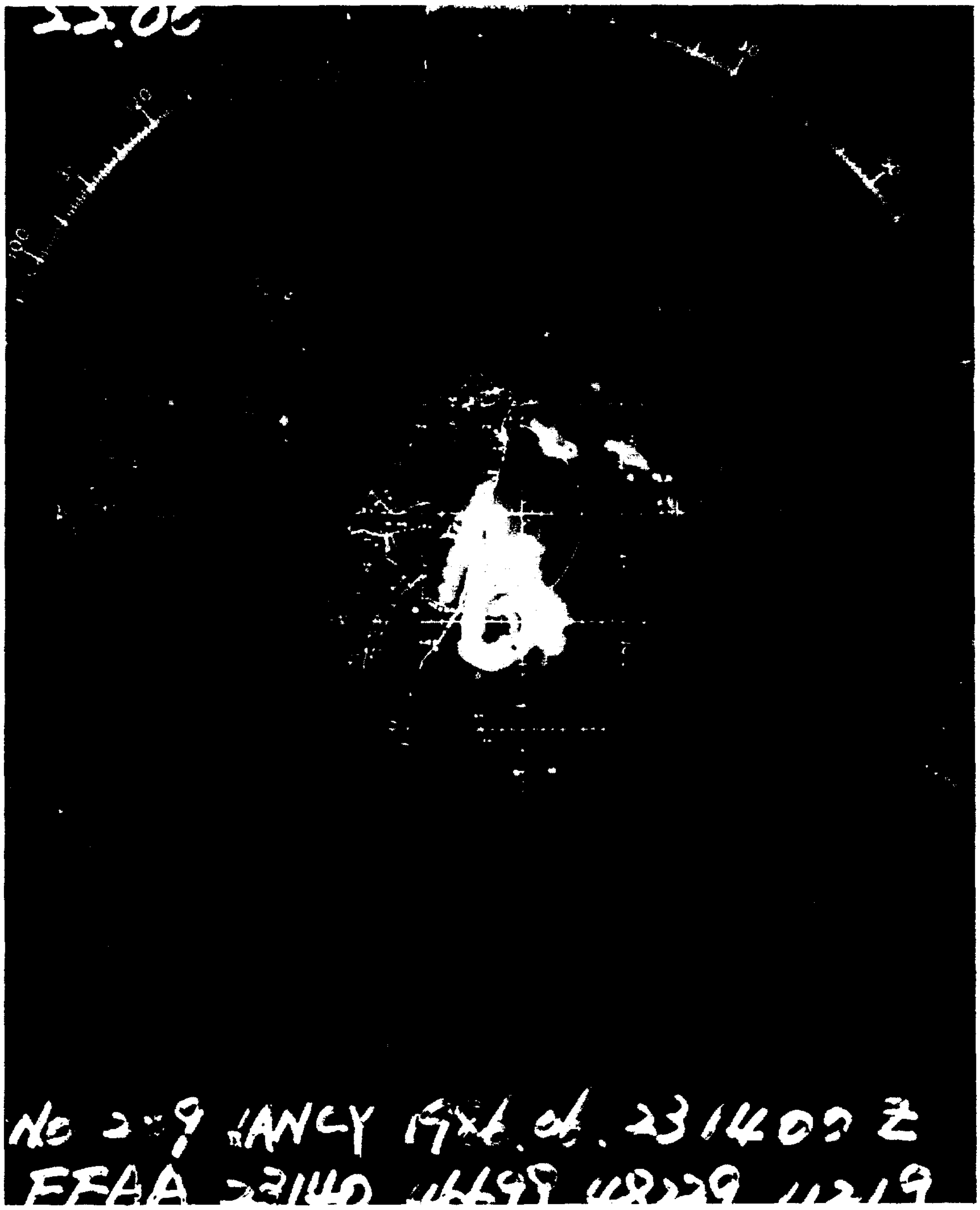


Figure 3-05-2. The eye of Typhoon Nancy as seen by radar from Hualien, Taiwan (WMO 46699) at 231400Z June (Photograph courtesy of Central Weather Bureau, Taipei, Taiwan).

proved most valuable and indicated the low-level center was displaced at least 60 nm (111 km) northwest of the 241800Z warning position. This warning position had been extrapolated from the previous warning. Unfortunately, the 241200Z warning was based on a low confidence nighttime position from infrared satellite imagery that was suspect, since Nancy was undergoing extratropical transition. The amended 241800Z warning, which followed immediately and was based on aircraft reconnaissance data, correctly forecast Nancy's movement through the Korea Straits instead of over the island of Kyushu, Japan. By that time increased vertical wind shear and entrained cooler, drier air had taken their toll on the tropical cyclone. Nancy continued to move rapidly northeastward through the Korea Strait and maintained the strongest low-level winds in the southeast semicircle. Southern Korea received torrential rains, which inundated 22,477 acres (9100 hectares) of farmland. Twelve people were reported dead or missing, as a result of the flooding.

Satellite analysis early on 25 June indicated extratropical transition had occurred in the Sea of Japan. The system was finalled on the 250600Z warning as the residual low pressure area swept eastward across northern Honshu 12-hours later.

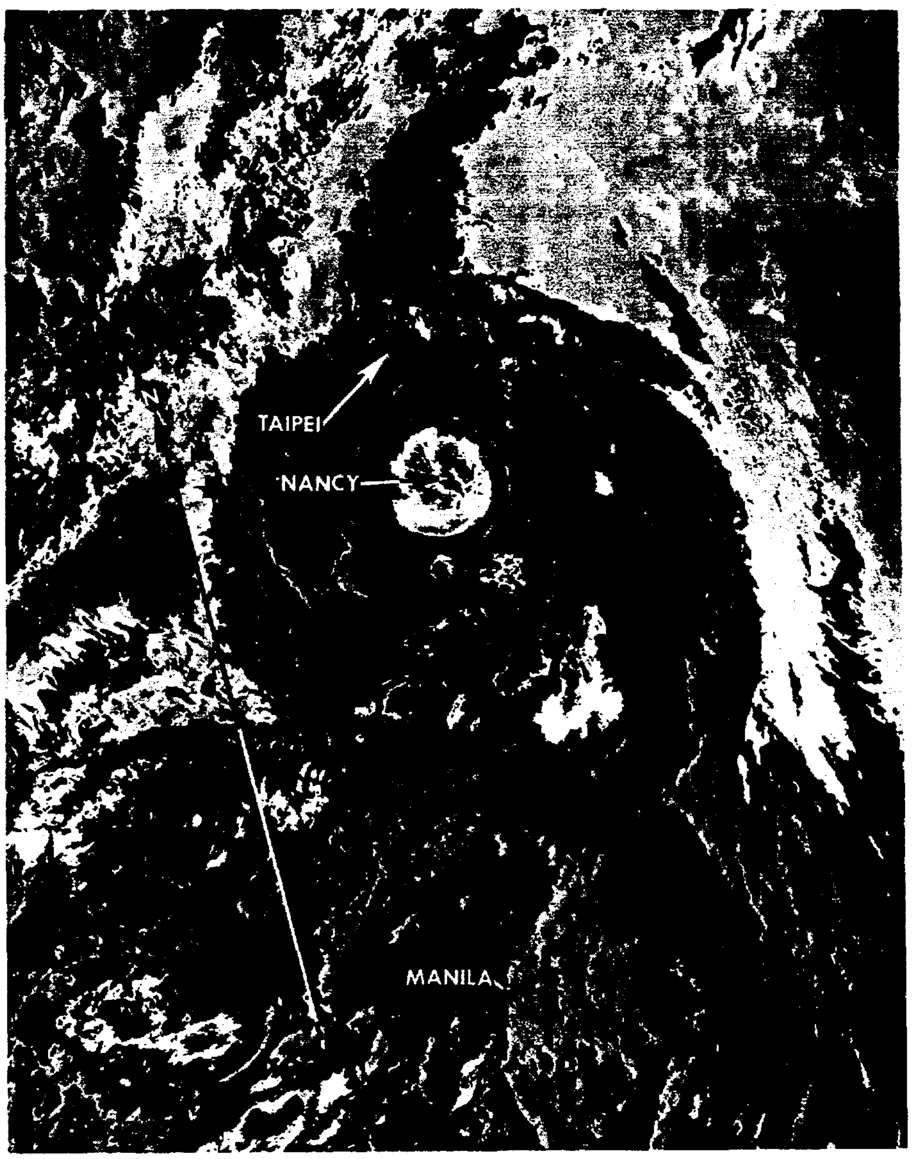
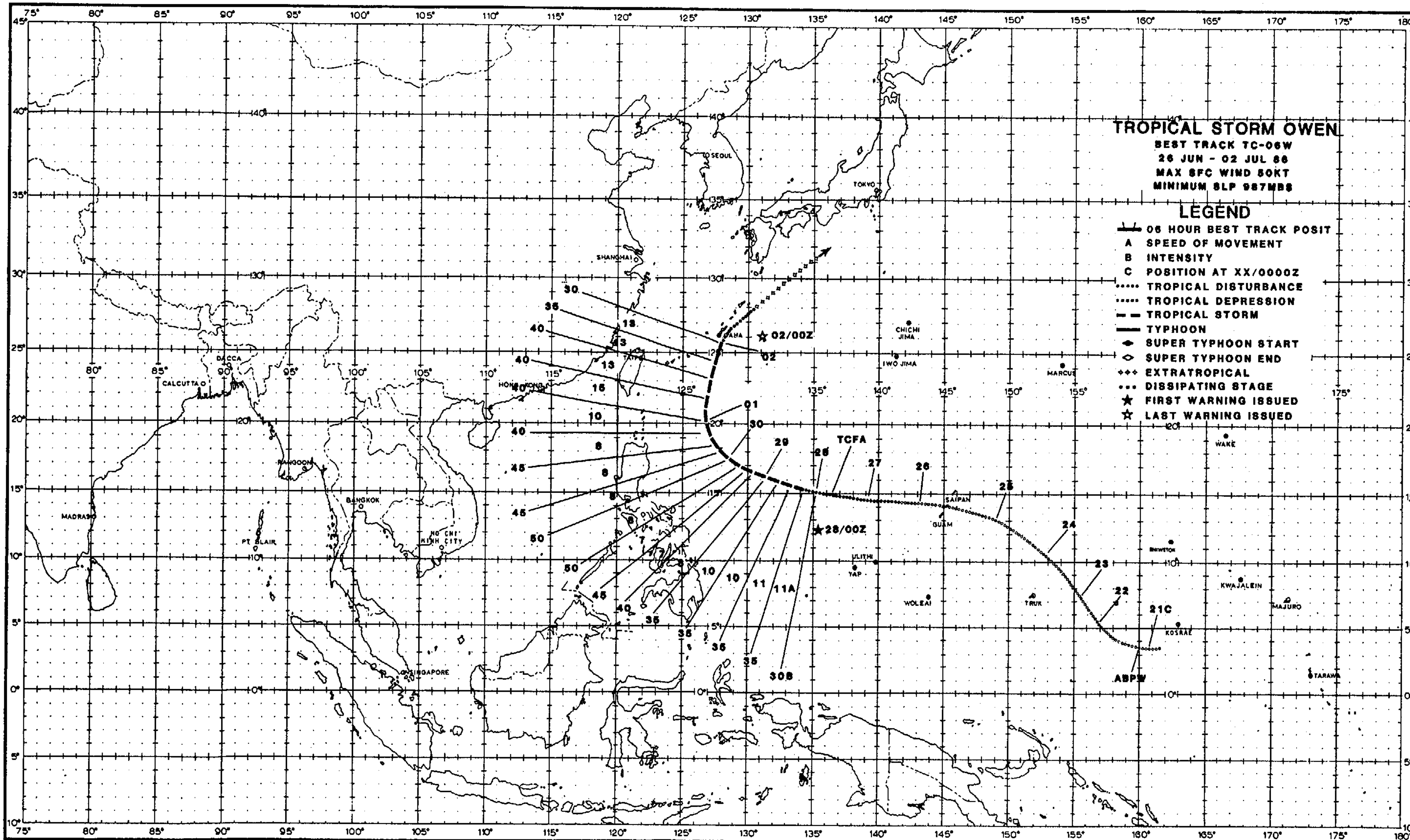
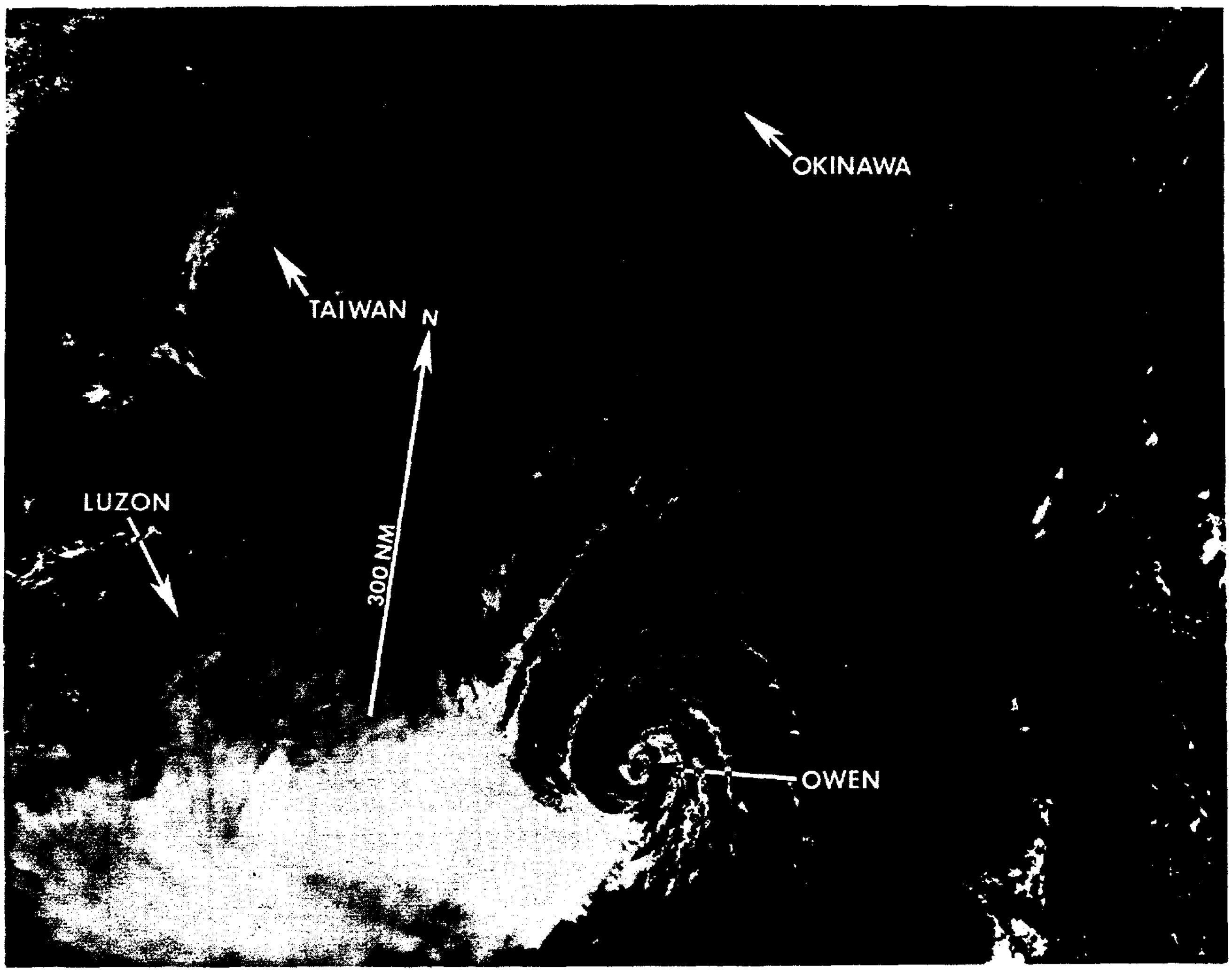


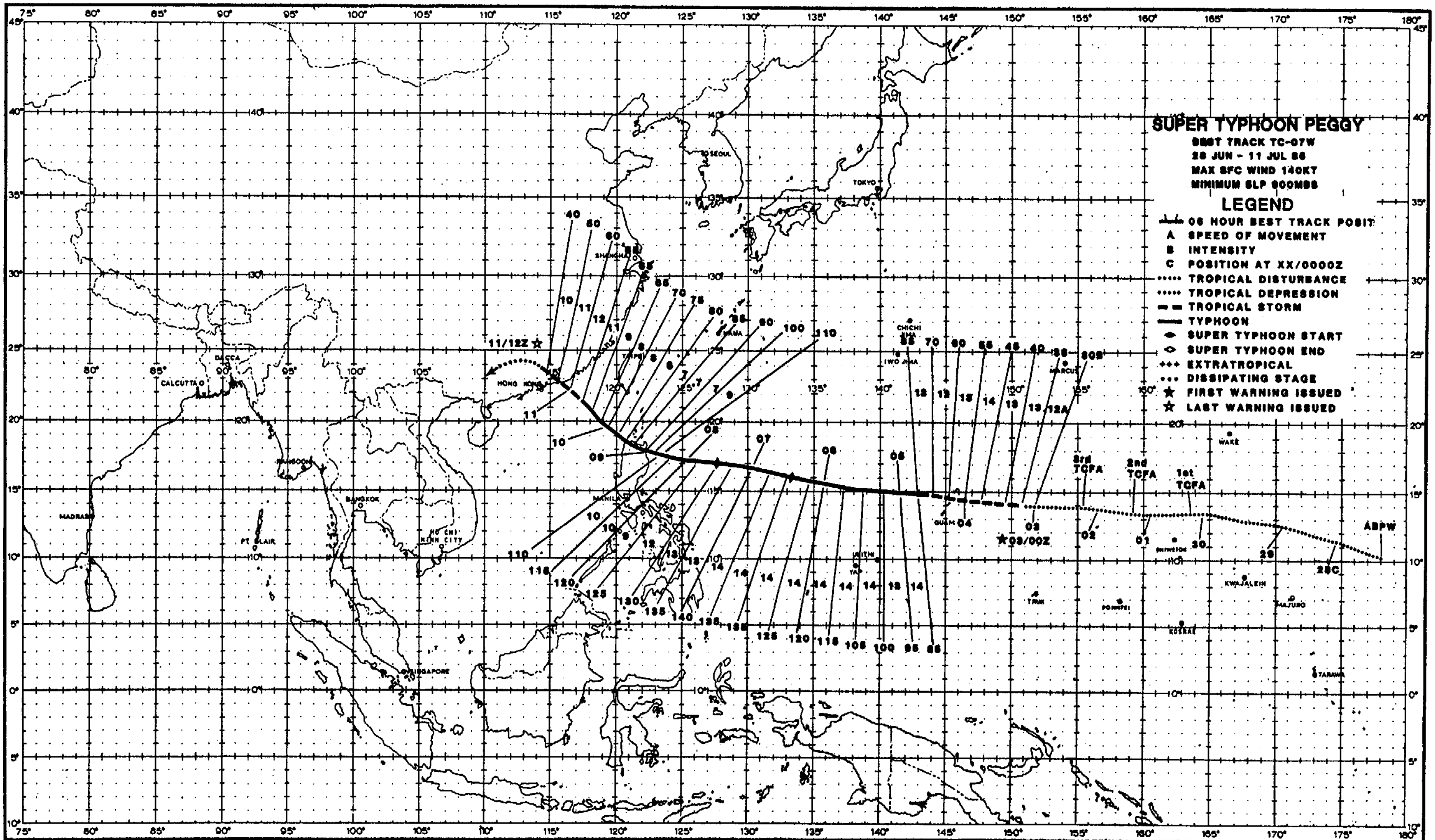
Figure 3-05-3. Specially enhanced infrared image of Typhoon Nancy's eye. The gray shading, which is used in conjunction with the Dvorak enhanced infrared technique, can provide an estimate of the intensity of the tropical cyclone (231428Z June DMSP infrared imagery).



NOCC GUAM 3142/20 (NEW 5 - 80)

Figure 3-06-1. Tropical Storm Owen had a long history as a disturbance. It was first noted as a suspect area on the Significant Tropical Weather Advisory (ABPW PGTW) at 0600Z on the 21st of June. As the system became more organized, its intensity increased. This prompted the issuance of a Tropical Cyclone Formation Alert at 271800Z when it was west of Guam in the Philippine Sea. Based on aircraft reconnaissance reports (272325Z) of 30 kt (15 m/sec) maximum sustained winds and a minimum sea-level pressure of 1001 mb, JTWC began warning on the system at 280000Z. On the 29th, Owen reached its maximum intensity of 50 kt (26 m/sec). As Owen moved northwestward around the periphery of the subtropical ridge, it came into an area of increased vertical shear. This resulted in the deep convection becoming displaced toward the west-southwest. By the 2nd of July, it had lost its tropical characteristics and dissipated over water. The imagery shows Owen's exposed low-level circulation center during the system's weakening phase (300108Z June DMSP visual imagery).





NOCC GUAM 3142/20 (NEW 5 - 80)

Peggy was the second super typhoon of the 1986 WESTPAC season. With the help of the Theta-E intensity forecast technique, intensity errors were kept to a minimum. In contrast, forecast track problems arose due to erroneous guidance from the One-way Interactive Tropical Cyclone Model (OTCM) which had a consistent northward bias at 72-hours.

During the latter part of June, the low-level, low-latitude tropical easterlies between the eastern Caroline Islands and the International Dateline were weaker than normal. In this area between the equator and 10 North Latitude, the light and variable winds, in conjunction with the tropical easterlies to the north, formed a vortex 600 nm (1111 km) east of Kwajalein Atoll in the Marshall Islands. It was first mentioned on the 270600Z June Significant Tropical Weather Advisory (ABPW PGTW) after satellite imagery showed persistent convection had developed. The circulation moved west-northwestward for six days before reaching tropical storm intensity (35 kt (18 m/sec)) 350 nm (648 km) east of Guam. Throughout this period the cloud signature caused heightened concern for Guam, however aircraft reconnaissance flights did not locate any supporting strong winds. At 030000Z July, JTWC issued its first warning on Tropical Depression 07W based on maximum winds of 25 kt (13 m/sec) from synoptic reports and the potential for intensification near Guam. Twelve hours later Peggy was upgraded to a tropical storm, when aircraft reconnaissance found a band of 35 kt (18 m/sec) surface winds displaced 20-40 nm (37-74 km) northwest of the vortex center.

Continuing to move west-northwestward, Peggy passed 58 nm (107 km) north of Guam at 040700Z. Peak winds experienced on Guam were 28 kt (14 m/sec) with gusts to 48 kt (25 m/sec). There was limited damage to Guam, restricted primarily to power poles and crops. The islands of Rota, Tinian and Saipan experienced more extensive damage - primarily to crops.

During the period 042352Z to 062040Z, Peggy's mean sea-level pressure (MSLP) dropped from 973 mb to 900 mb - a decrease of 73 mb. This corresponds to a drop of approximately 1.6 mb/hour which is classified

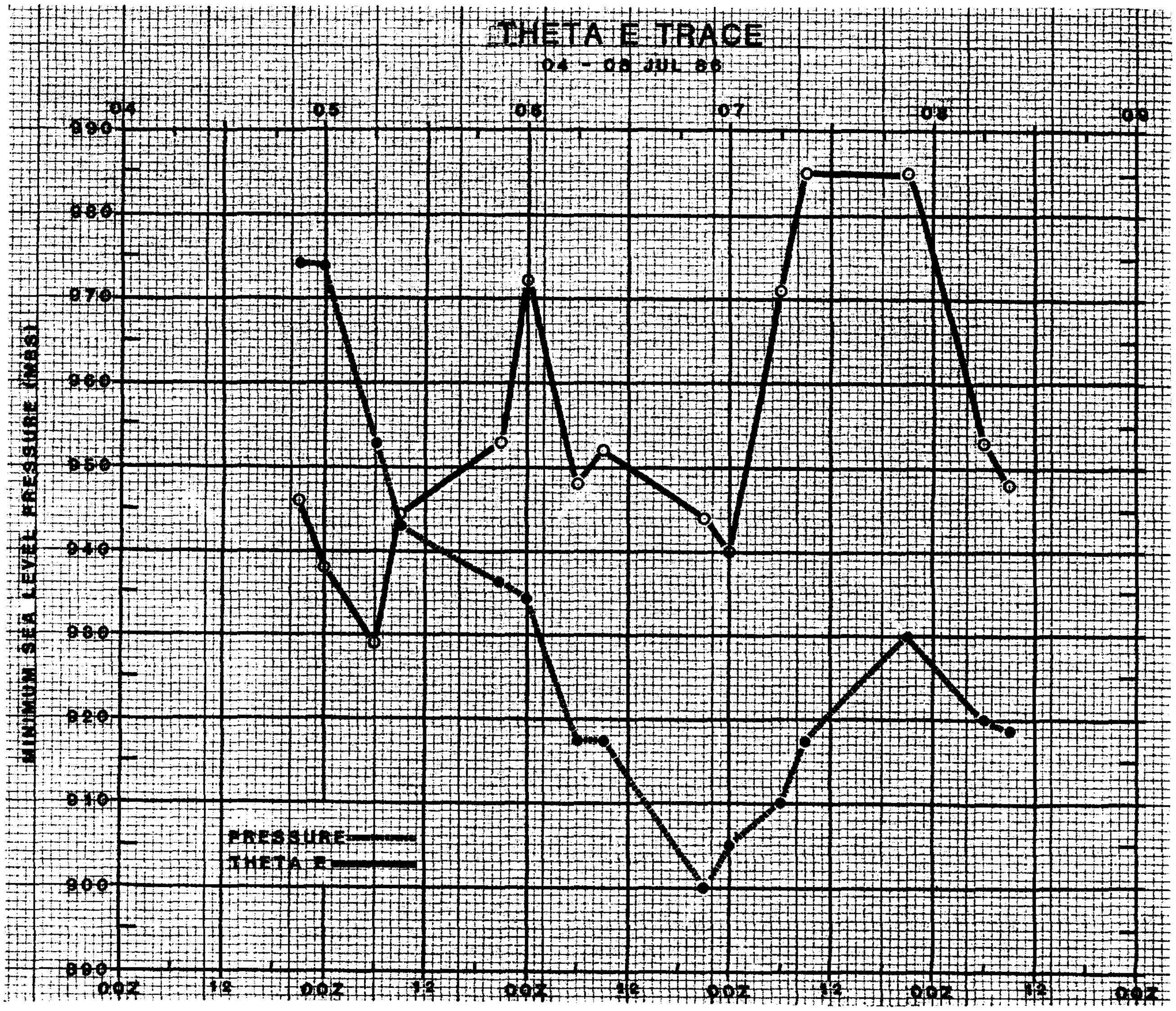


Figure 3-07-1. Plot of Peggy's central minimum sea-level pressure and the Theta-E line with the intersection at 050800Z. Rapid deepening occurred with a 1.6 mb/hour drop in central pressure from 973 mb to 900 mb.

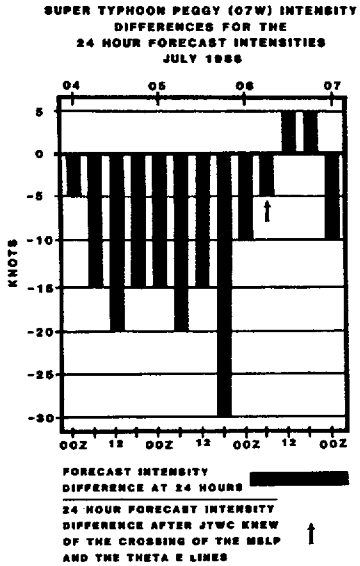


Figure 3-07-2. A graph of the difference between the actual best track intensities and the 24-hour forecast intensities before and after JTWC knew the sea-level pressure and Theta-E line intersected (reference Figure 3-07-1).

as rapid deepening (Holliday and Thompson, 1979). The rate of deepening does not meet the 2.5 mb/hour criterion used to define explosive deepening. As mentioned earlier, JTWC was able to significantly decrease forecast intensity errors, with the guidance provided by Theta-E intensity forecast technique (Dunnavan, 1981). The technique uses equivalent potential temperature (Theta-E), calculated from aircraft recon 700 mb temperature and dew point reports, as a measure of the tropical cyclone's thermodynamic energy. When the plots of Theta-E and MSLP intersect near the critical values of 950 mb and 360 degrees Kelvin, central pressure can be expected to drop to below 925 mb. Figure 3-07-1 shows the plot of Peggy's Theta-E and MSLP values during the period 042050Z to 080856Z. The intersection point is at 050800Z. The graph of the 24-hour forecast intensity (Figure 3-07-2) demonstrates the difference before and after the knowledge of the Theta-E crossing. The average 24-hour forecast intensity error before 050600Z (the first foreknowledge of increased potential for explosive or rapid deepening) was 16 kt (8 m/sec). The average 24-hour forecast intensity error after 050600Z was 5 kt (3 m/sec). With regard to 48-hour forecast intensities, only one warning benefited because two days after 050600Z, Super Typhoon Peggy's intensity peaked at 140 kt (72 m/sec).

Figure 3-07-3 shows Super Typhoon Peggy at its maximum intensity. Peggy remained on the west-northwestward track and slammed into northern Luzon at 082200Z with 95 kt (49 m/sec) surface winds. Newspaper accounts of Peggy's fury reported ninety-three people died, 16 were missing, over 116,000 families were homeless, and damage was estimated at 2.5 million dollars. Most of this damage, primarily to crops and villages, was the result of torrential rain. Also, two people lost their lives in southern Taiwan.

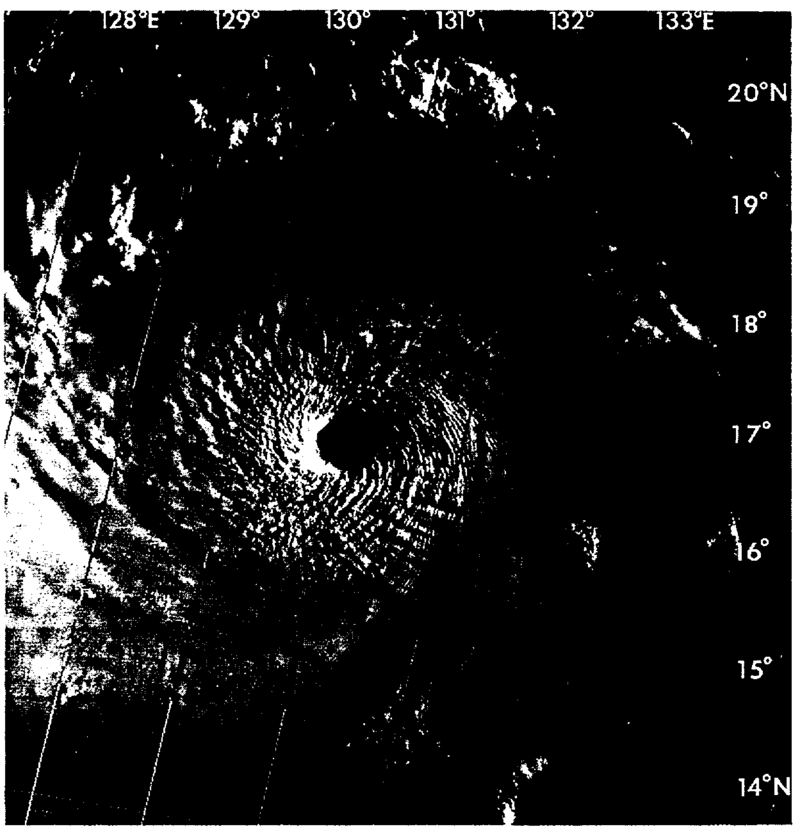


Figure 3-07-3. Super Typhoon Peggy at maximum intensity of 140 kt (72 m/sec) (062120Z July DMSP visual imagery courtesy of H and HS Weather, MCAS Futenma).

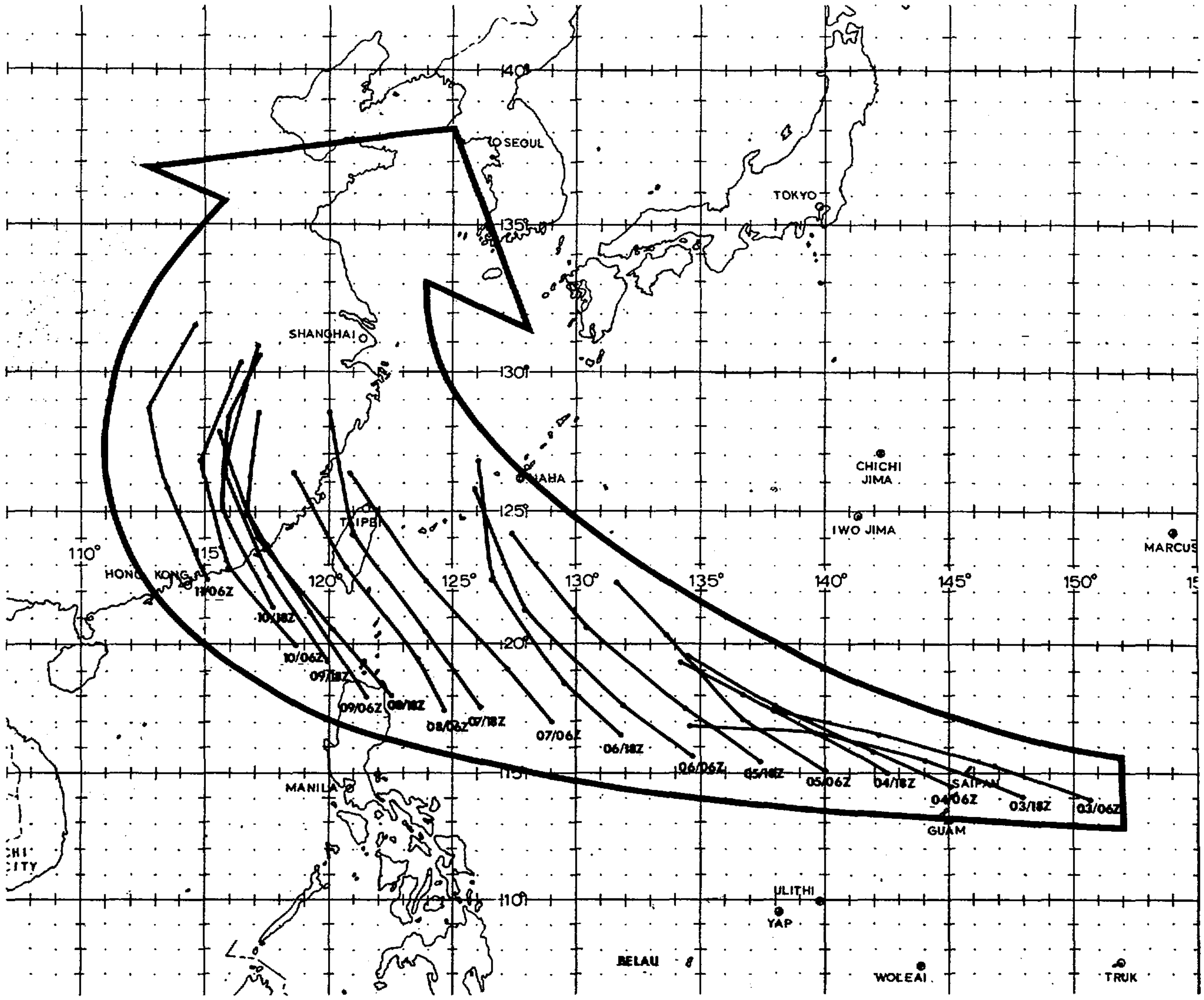


Figure 3-07-4. Plot of OTCM guidance through 72-hours for each twelve hour period. Note the continuous northward bias from the loci of initial points.

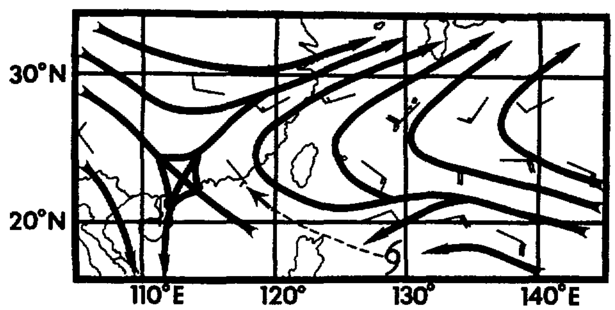
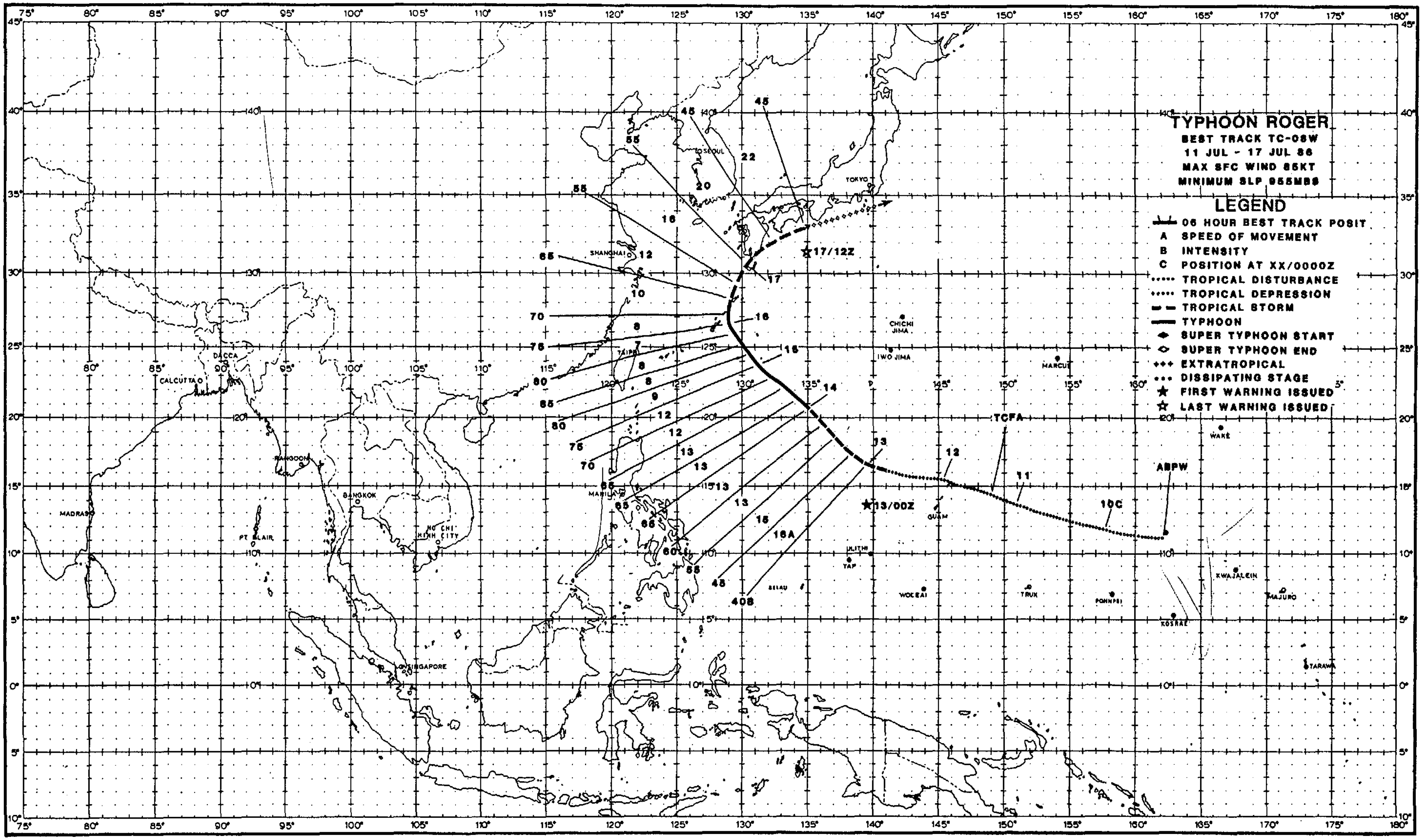


Figure 3-07-5. The 400 mb Numerical Variational Analysis (NVA) for 071200Z July with Peggy's position. The effect of the subtropical ridge can be implied from the plot of the final best track.

After crossing northern Luzon and moving into the South China Sea, Peggy continued to slowly weaken. It made landfall over southern China 80 nm (148 km) east of Hong Kong at 110200Z with an intensity of 55 kt (28 m/sec) Widespread flooding resulted across southern China and over 200 people were reported dead.

The track forecasts from the first warning through the 21st warning (at 080000Z) repeatedly called for a more northerly track than was observed. Guidance from the OTCM hinted at recurvature (Figure 3-07-4). Initially the NOGAPS prognoses, 021200Z to 060000Z, indicated slow weakening of the subtropical ridge poleward of Peggy. However, from 061200Z through 120000Z the NOGAPS prognoses reversed this trend and began slow ridge building. Although NOGAPS suggested a stronger subtropical ridge, guidance from OTCM persistently called for a more northerly track. The 400 mb NVA analysis at 071200Z (Figure 3-07-5) shows the location of the ridge and Peggy's ultimate track.



NOCC GUAM 3142/20 (NEW 5 - 80)

Typhoon Roger was initially enhanced by a Tropical Upper-Tropospheric Trough (TUTT) cell as described by Sadler (1976). On 4 July 1986, as Typhoon Peggy was moving toward the west, away from Guam, a TUTT cell was observed moving west-northwestward from a location 780 nm (1445 km) east of Wake Island. The well-developed TUTT cell and its associated convection continued this movement for the next five days. By 8 July, a tropical disturbance had developed from this area of convection about 30 nm (56 km) southwest of Enewetak Atoll. It persisted into the next day when it was included in the Significant Tropical Weather Advisory (ABPW PGTW) for the first time. Initially, Roger showed little potential for development into a tropical disturbance. Over the next two days, however, the convective area became more organized as cross-equatorial westerlies converged with the tradewind easterlies at low-levels and an anticyclone formed aloft.

The divergent upper-level flow southeast of the TUTT cell continued to provide a favorable environment for the tropical disturbance to develop slowly during the next three and a half days. A Tropical Cyclone Formation Alert (TCFA) was issued for the system at 110717Z. Satellite imagery (Figure 3-08-1) at 120024Z July shows the tropical depression. The first warning was issued at 130000Z, because the system continued to increase in convective organization and a minimum sea-level pressure of 999 mb was observed by aircraft reconnaissance at 122245Z.

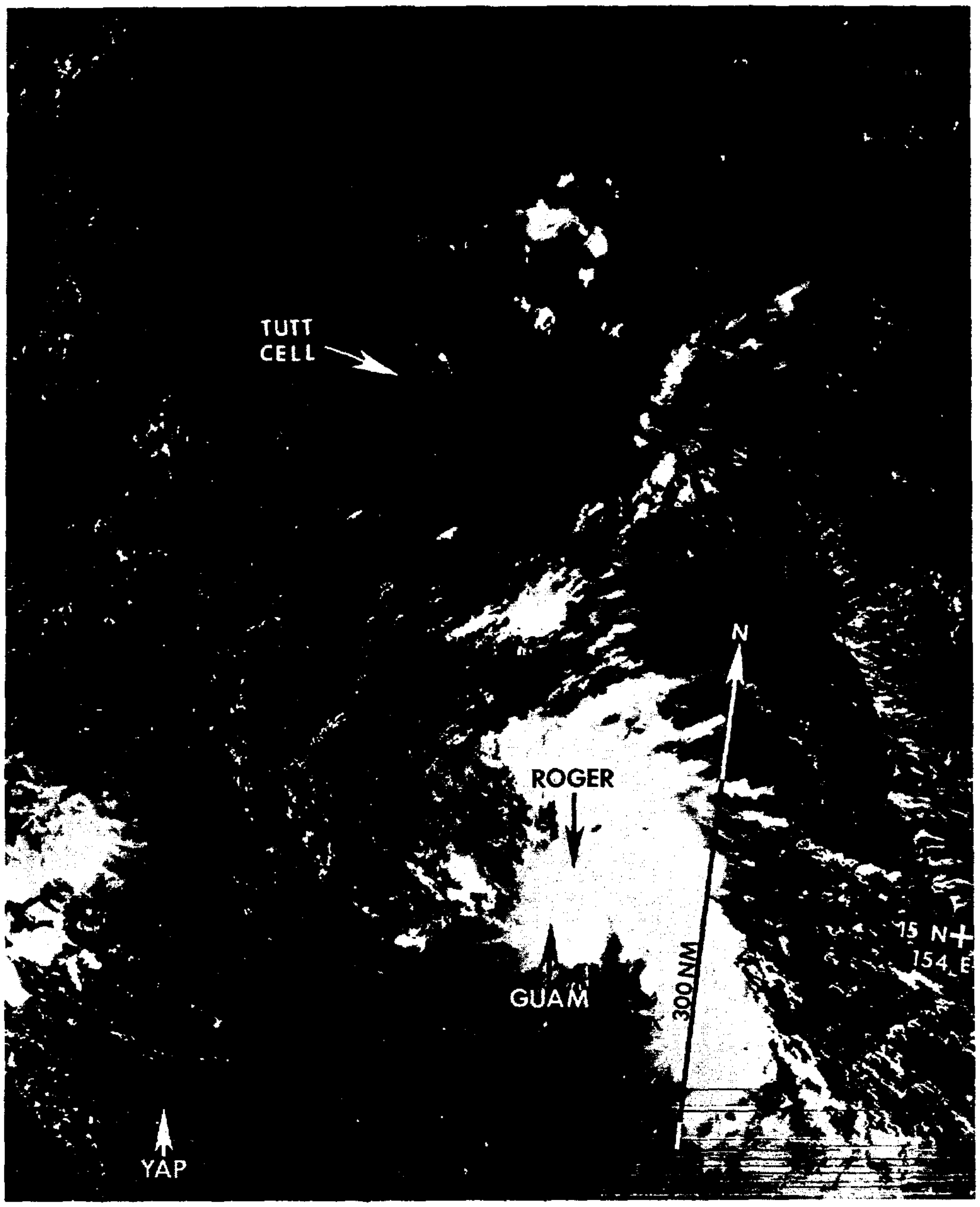


Figure 3-08-1. Roger as a tropical depression. Note the effect of the TUTT cell northwest of the depression which causes a deformation and enhancement of the cirrus outflow pattern to the southeast (120024Z July DMSP visual imagery).

During all stages of development, Typhoon Roger remained small in size. Aerial Reconnaissance Weather Officers flying into Roger consistently reported the diameter of the light and variable surface wind center as 1 nm (2 km) to 4 nm (7 km). Figure 3-08-2 shows Roger's small eye and central convective mass.

JTWC accurately forecast Roger's track and point of recurvature. Roger moved west-northwestward while south of the 700 mb subtropical ridge; then northward, and later northeastward as it recurved around the western end of the ridge. Figure 3-08-3 shows the location and orientation of the subtropical ridge as reflected in the 700 mb data on 131200Z July. The guidance from the One-way Interactive Tropical Cyclone Model (OTCM), JTWC's primary forecast aid, was generally good although the model repeatedly suggested a tighter recurvature track at the 24-hour point (approximately 180 nm (333 km) farther to the east) than was actually observed. Figure 3-08-4 is a plot of the initial and 24-hour points from the OTCM showing this bias toward the east.

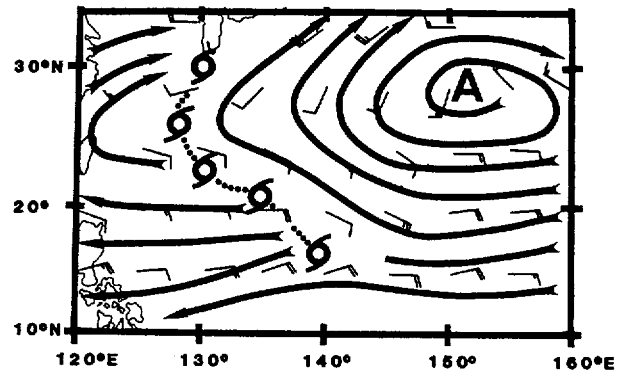


Figure 3-08-3. The 700 mb Wind Analysis on 131200Z July showing location and orientation of the subtropical ridge that influenced Roger's movement. The dashed line shows Typhoon Roger's eventual track.

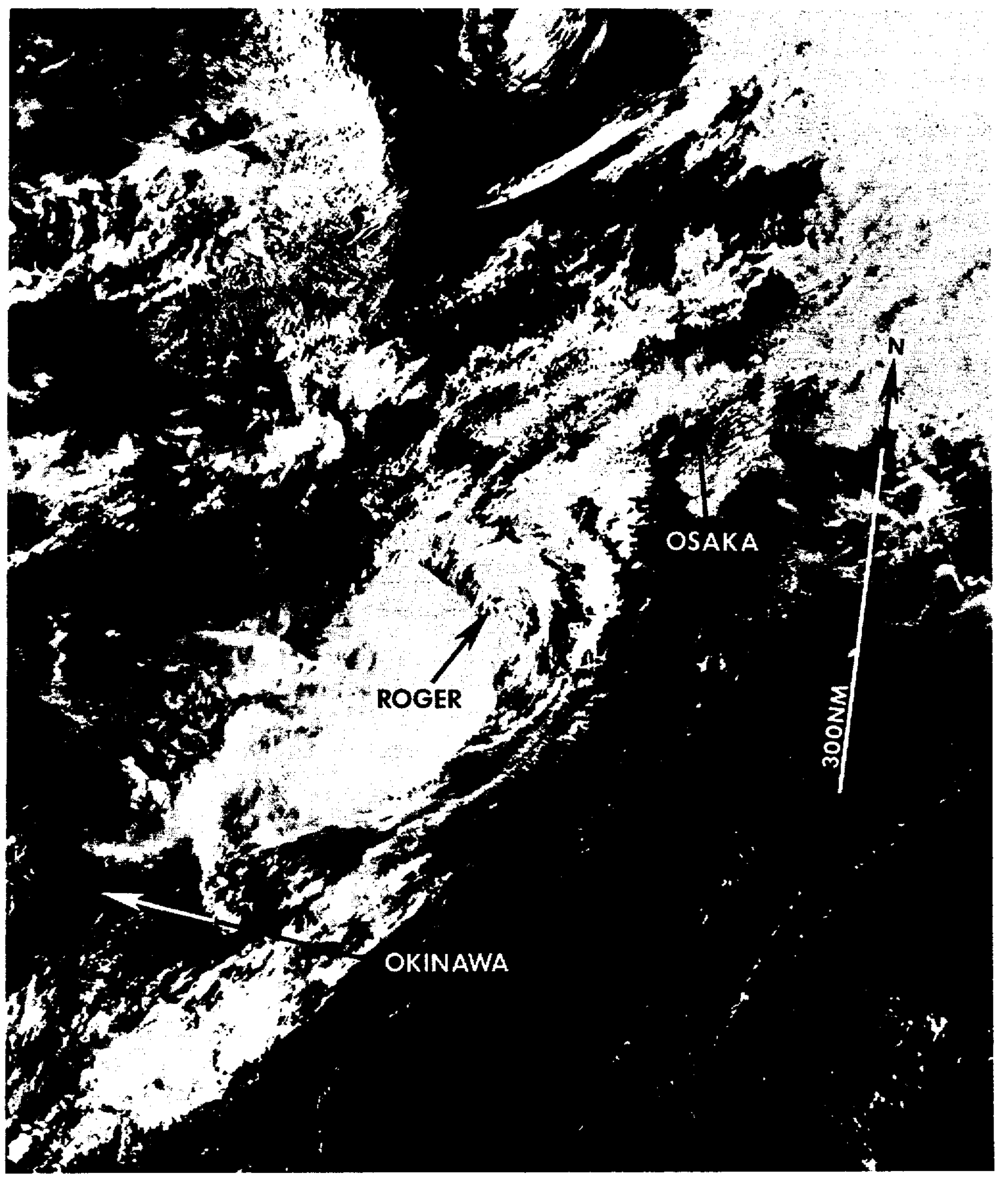


Figure 3-08-2. Typhoon Roger near maximum intensity. A small eye is present in the central convective mass (150104Z July DMSP visual imagery).

After recurvature toward the northeast, Typhoon Roger began extratropical transition as it encountered the shearing environment that caused its convection to be displaced to the southwest of the low-level circulation center (Figure 3-08-5). This shearing away of the central convection caused Roger to weaken further. The stratified nature of the low-level cloud (in Figure 3-08-5) is indicative of extratropical transition.

Although Typhoon Roger passed just 45 nm (83 km) east of the island of Okinawa and Kadena Air Base, the effect was minimal due to its small size. Peak gusts of 43 kt (22 m/sec) were reported and the northern part of the island received about 1 inch (254 mm) of rainfall. "U.S. military installations on Okinawa spent most of Wednesday (16 July) in typhoon condition one .... (and) Japanese schools were closed during the day. Approximately 4000 tourists were stranded briefly at Naha Airport during the day as 21 flights were cancelled because of the storm. Airline officials said all those passengers were on their way by late afternoon." There were no reports of injuries or significant damage on Okinawa or to shipping.

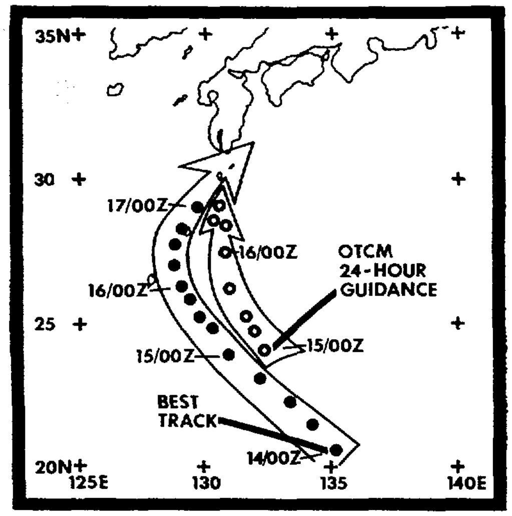


Figure 3-08-4. Plot of OTCM (One-way Interactive Tropical Cyclone Model) forecast tracks for period 140000Z to 161800Z July.

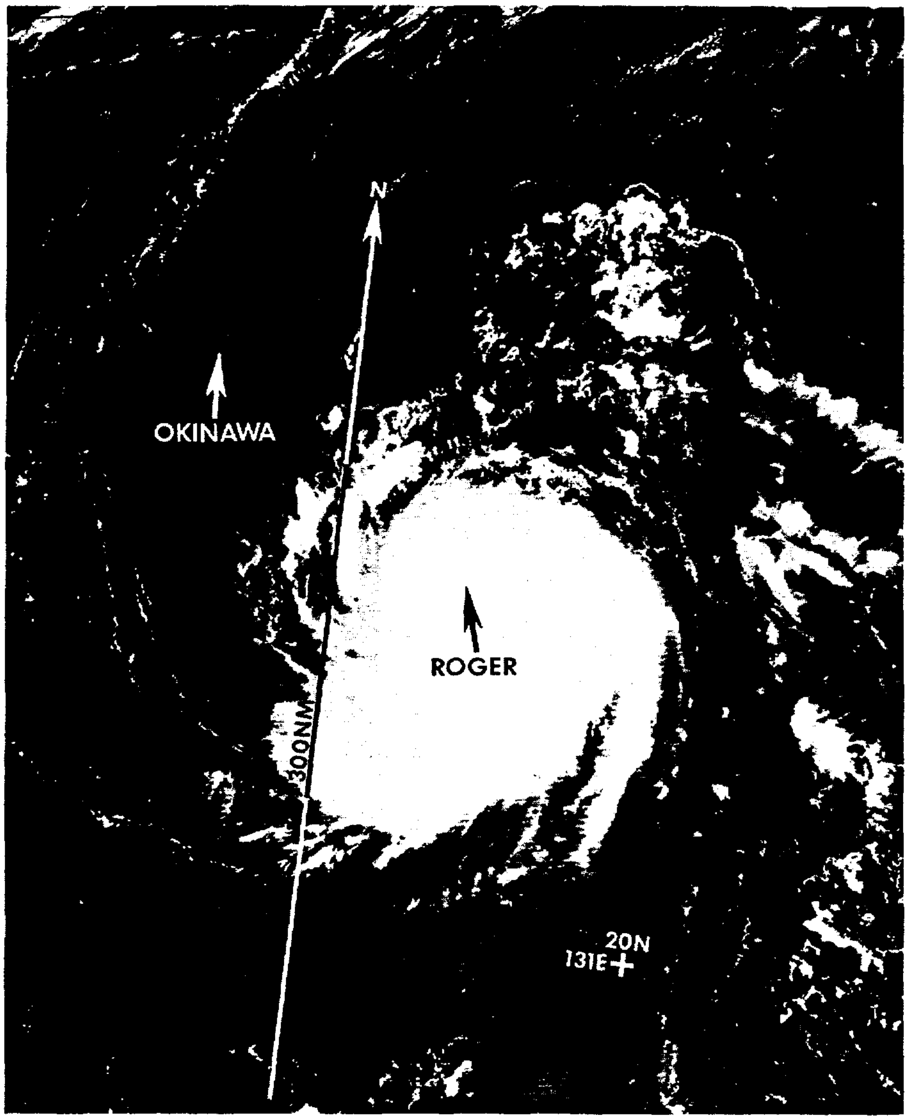
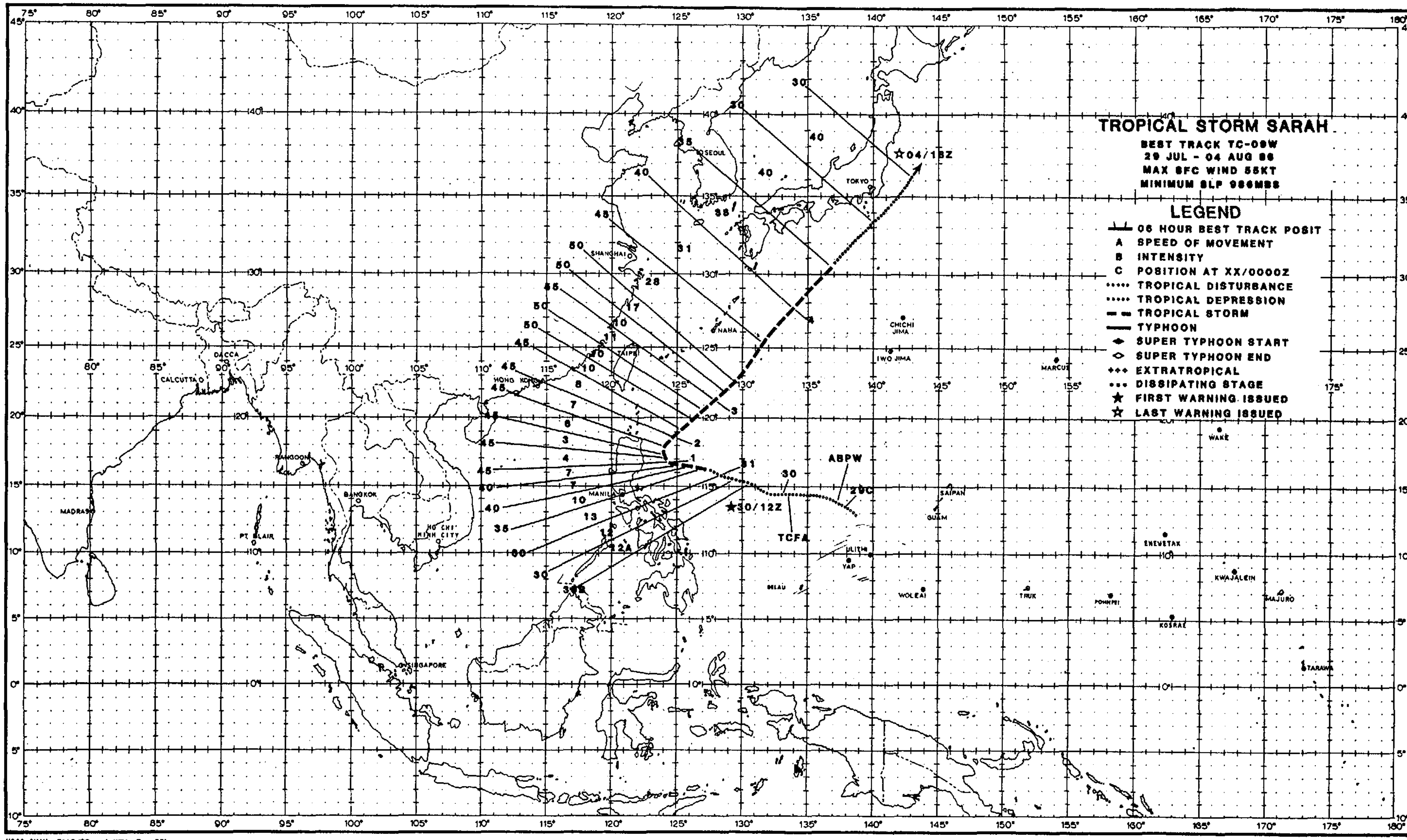


Figure 3-08-5. Satellite imagery of Roger showing the exposed low-level circulation center and central convection displaced to the southwest. Note the stratified nature of the low-level clouds associated with extratropical transition (170527Z July NOAA visual imagery).



NOCC GUAM 3142/20 (NEW 5 - 80)

The summer monsoon was well established and had stronger than normal low-level westerlies from the Caroline to the Marshall Islands by mid-July. From the 21st of July onward, the conditions were ripe for cyclogenesis. After daily mention in the Significant Tropical Weather Advisory (ABPW PGTW) and several false alarms, a Tropical Cyclone Formation Alert (TCFA) was issued for a rapidly developing area of convection in the Philippine Sea 420 nm (778 km) north of Belau.

The aircraft reconnaissance flight investigating this disturbed area at 300152Z located a weak, low-level circulation center with maximum surface winds of 18 kt (9 m/sec) and a minimum sea-level pressure (MSLP) of 1001 mb. The first warning for Tropical Depression 09W followed at 301200Z as convection and winds increased on the south side of the vortex.

Subsequent intensification of this system was masked from satellite imagery by the heightened convective activity in the monsoonal westerlies. Aircraft reconnaissance into the tropical cyclone at 311525Z found 40 kt (21 m/sec) surface winds, which prompted the upgrade to Tropical Storm Sarah. During this period, the tropical cyclone's west-northwestward movement slowed and the system, which appeared to be following an under-the-ridge scenario, continued to consolidate.

Later aircraft reconnaissance at 3112138Z and 010009Z confirmed the slowing trend and the Aerial Reconnaissance Weather Officer (ARWO) reported that multiple circulation centers might be present. Additionally, the ARWO estimated the ring of maximum surface winds as nearly symmetrical with slightly weaker winds in the northern semicircle displaced 20 to 60 nm (32 to 96 km) from the center.

As Sarah moved closer to the island of Luzon, it became increasingly more difficult to locate the circulation center. The major convective area shifted to the northwest quadrant (see Figure 3-09-1). Aircraft reconnaissance at 011300Z (Figure

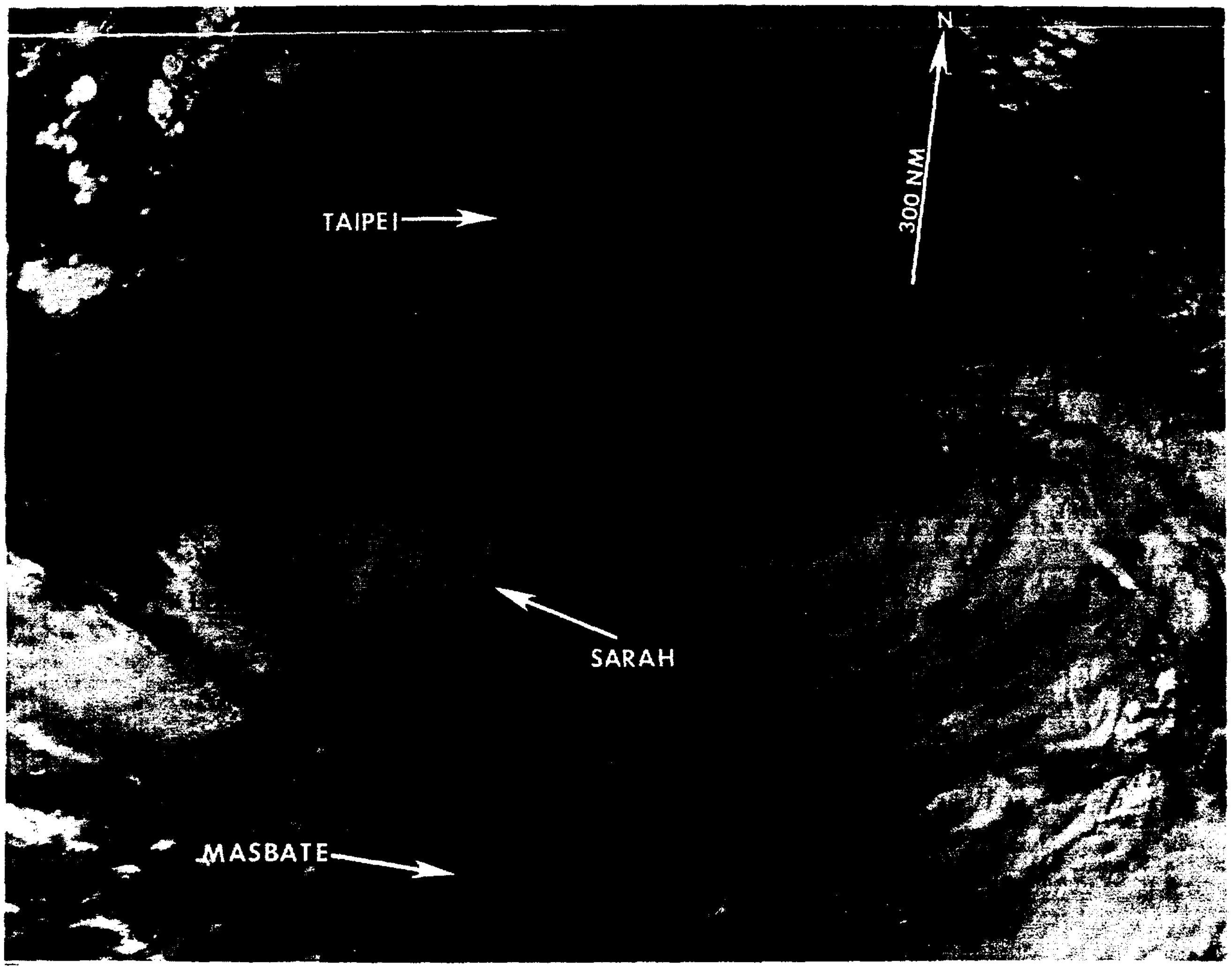


Figure 3-09-1. "Where is Sarah?" That was the question when this image was received. The trend from previous satellite imagery was for the deep convection to continue westward movement across northern Luzon appears to be maintained (010608Z August NOAA visual imagery).

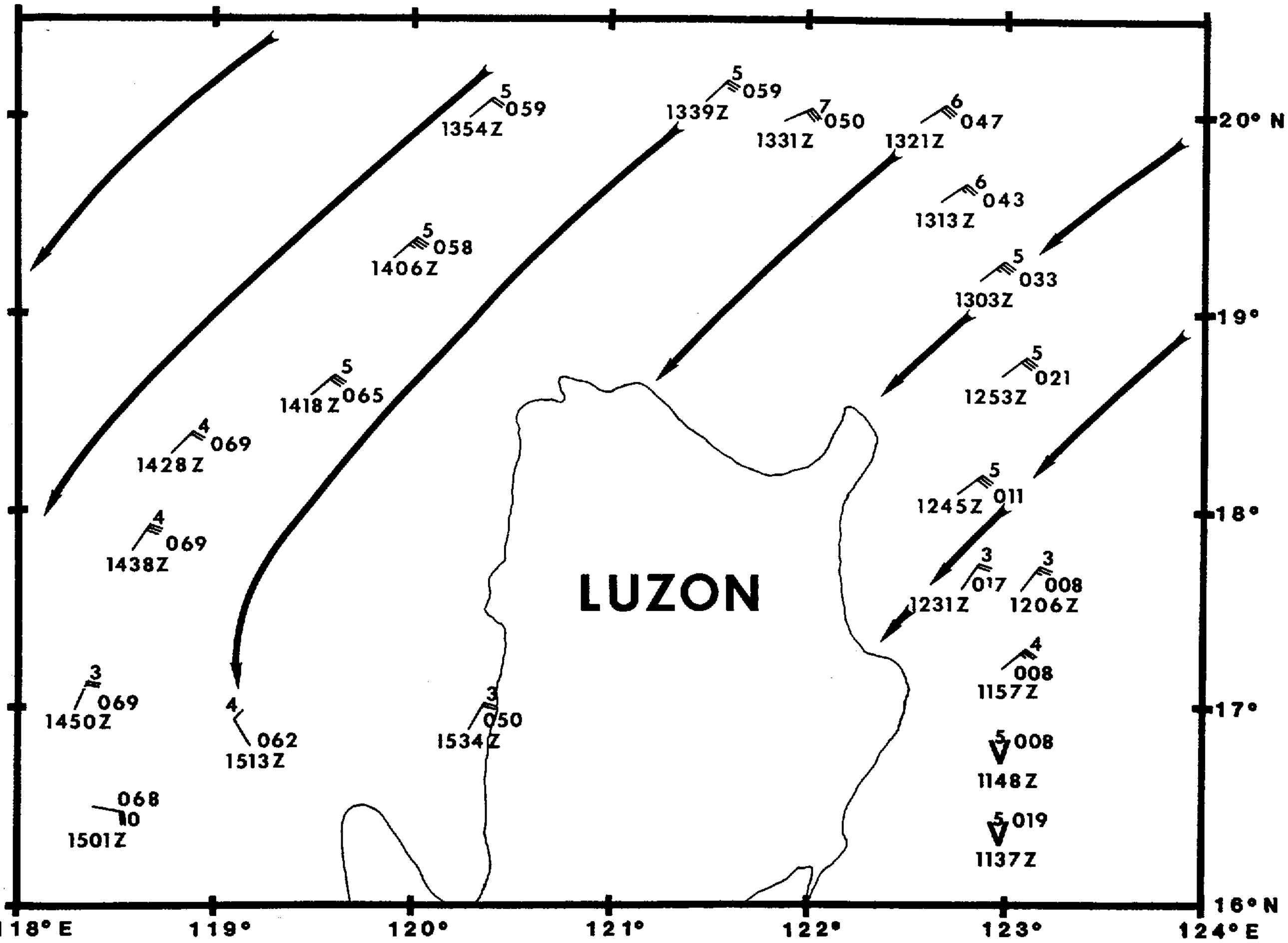


Figure 3-09-2. A plot of the 011300Z August aircraft reconnaissance mission around northern Luzon. These data imply that the low-level circulation in the monsoon trough (i.e., Sarah) may have remained in the Philippine Sea.

3-09-2) flew around northern Luzon and detected only broadscale northeasterly flow without a trace of a low-level circulation center. These northeasterly winds should have provided a valuable clue as to the location of Sarah. (In retrospect, it took more than 24-hours to get the forecast back on the right track.) In the interim, the persistent deep cloudiness across northern Luzon as viewed by the meteorological satellite imagery implied that Sarah was continuing into the South China Sea and towards mainland China. The dynamic guidance provided by Nested Tropical Cyclone Model (NTCM) and One-Way Interactive Tropical Cyclone Model (OTCM) endorsed this movement into the South China Sea.

Again, aircraft reconnaissance between 012100Z and 020000Z was unable to locate a Sarah. This time the flight was west of Luzon in the South China Sea. An aircraft mission previously scheduled to investigate a TCFA area northeast of Luzon, however, did find Sarah in the Philippine Sea. Satellite imagery after 012100Z also showed a reorganization of deep convection east of Luzon. This resulted in a relocation and an abrupt change in forecast philosophy. No longer was Sarah following the under-the-ridge scenario into the South China Sea, but now was moving northeastward (Figure 3-09-3).

After 030600Z August, Sarah started accelerating toward the northeast in response to increasing westerly wind flow aloft. By 050000Z, the system moved to a position east of the island of Honshu and transitioned to an extratropical cyclone.

Reanalyses of aircraft, satellite, radar and conventional data after-the-fact revealed the following. As Sarah approached northern Luzon, the upper-level circulation center became displaced from the low-level center and moved across the mountainous terrain of the island and dissipated in the South China Sea. The residual low-level vortex, which was weak and difficult to locate, remained east of Luzon in the active monsoon trough. The monsoon trough changed its orientation gradually from east-west to northeast-southwest, as Sarah reintensified and moved northeastward. The aircraft mission at 011300Z (Figure 3-09-2) was a key piece of data in reconstructing what happened in this difficult situation. The broad northeasterly flow across northern Luzon implied that Sarah remained in the Philippine Sea and was masked by the monsoon trough and vigorous convection closeby.

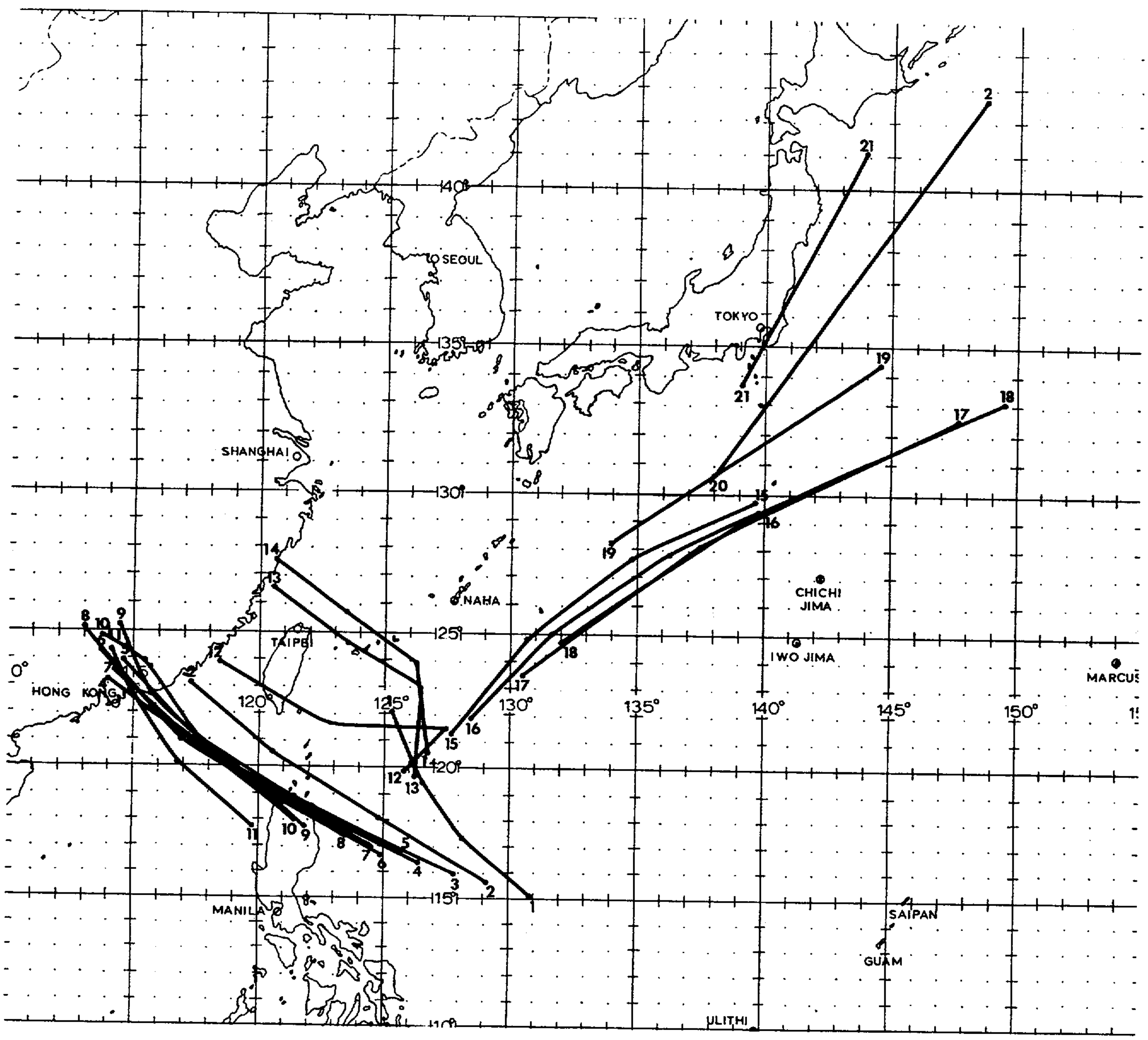
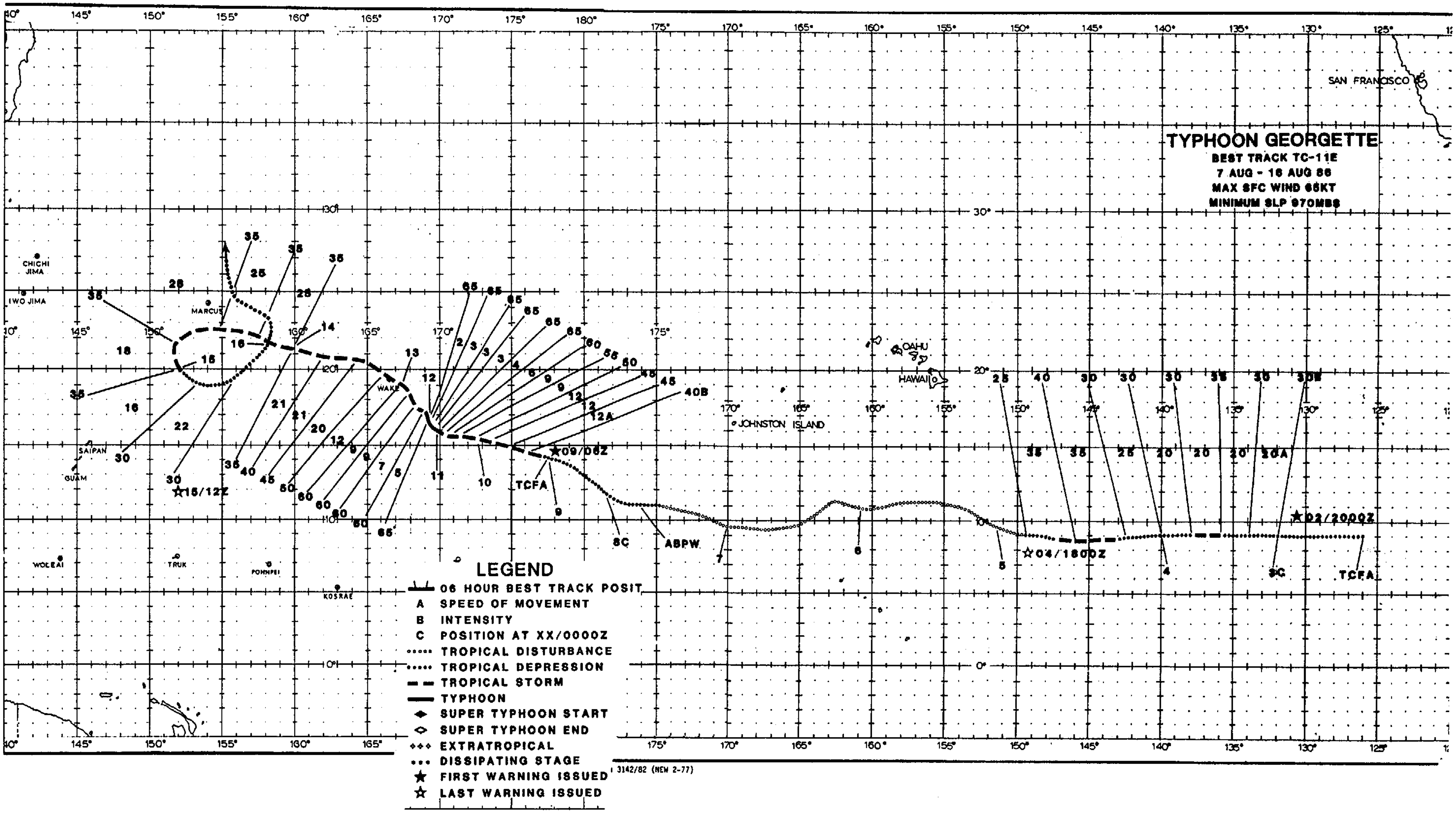


Figure 3-09-3. Plots of the forecast tracks for Sarah. Note the abrupt change between warnings 11 and 15. The difficulty in locating the low-level circulation center and understanding the changing synoptic situation prolonged the time (warnings 9 through 14) it took to get the forecasts back on the right track.


TYPHOON GEORGETTE
BEST TRACK TC-11E
7 AUG - 16 AUG 86
MAX SFC WIND 65KT
MINIMUM SLP 970MBS
LEGEND
06 HOUR BEST TRACK POSIT
A SPEED OF MOVEMENT
B INTENSITY
C POSITION AT XX/0000Z
TROPICAL DISTURBANCE
TROPICAL DEPRESSION
TROPICAL STORM
TYPHOON
SUPER TYPHOON START
SUPER TYPHOON END
EXTRATROPICAL
DISSIPATING STAGE
FIRST WARNING ISSUED
LAST WARNING ISSUED
SAN FRANCISCO
OAHU
HAWAII
JOHNSTON ISLAND
WAKE
MARCUS
CHICHI JIMA
IWO JIMA
SAIPAN
GUAM
WOLEAI
TRUK
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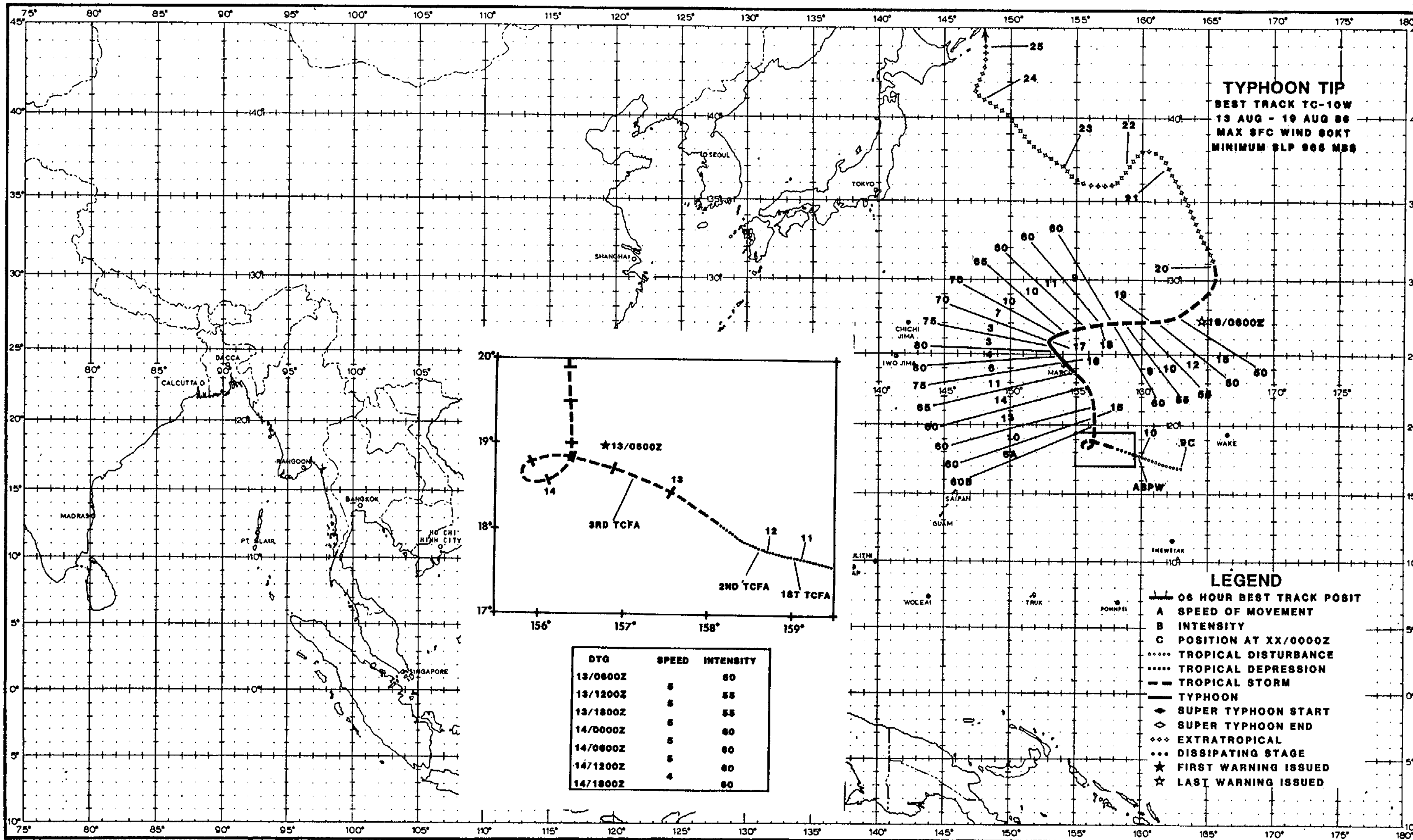
3142/82 (NEW 2-77)



DTG	SPEED	INTENSITY
13/0600Z		50
13/1200Z	5	55
13/1800Z	5	55
14/0000Z	5	60
14/0600Z	5	60
14/1200Z	5	60
14/1800Z	4	60

NOCC GUAM 3142/20 (NEW 5-80)

Typhoons Georgette and Tip provided one of the more intriguing forecasting opportunities of the 1986 western North Pacific Tropical Season for JTWC as they circled one another in a complex binary interaction. Georgette was a rare tropical cyclone which traveled from the eastern North Pacific region across the central region and became a typhoon in the western region (see Figure 3-10-1). During its two-week lifespan Georgette traveled nearly 5,600 nm (10,371 km).

Typhoon Georgette had an interesting early history. It began as a tropical disturbance in the eastern North Pacific 1,600 nm (2,963 km) south-southwest of Los Angeles on August 2nd and initially moved westward. The Naval Western Oceanography Center located in Pearl Harbor, Hawaii issued a Tropical Cyclone Formation Alert (TCFA) on the system at 020700Z after observing convective bands on satellite imagery. Later that same day, at 022000Z, the Eastern Pacific Hurricane Center (EPHC), located in San Francisco, issued the first advisory on Tropical Depression 11E. The system was upgraded to Tropical Storm Georgette (11E) on the fourth advisory at 031500Z, then downgraded to a tropical depression again on the fifth through seventh advisories when a decrease was noticed in the amount of convective organization. It was upgraded once more to a tropical storm on the eighth advisory and then finally downgraded for the last time and forecast to dissipate over water on the ninth advisory as it passed south of Hawaii. The Central Pacific Hurricane Center (CPHC) issued the sixth through ninth advisories after Georgette had moved into the central North Pacific. A total of nine advisories were issued on Georgette by EPHC and CPHC combined. All nine corresponding tropical cyclone warnings for the Department of Defense customers were issued by the Naval Western Oceanography Center.

Georgette maintained its identity as a tropical disturbance after the final downgrade and was tracked by JTWC before it crossed the dateline. It was first mentioned at 071500Z on the Significant Tropical Weather Advisory (ABPW PGTW) as a 20 kt (10 m/sec) disturbance 420 nm (778 km) southwest of Johnston Island. It crossed the dateline on 8 August while moving on a northwestward trajectory.

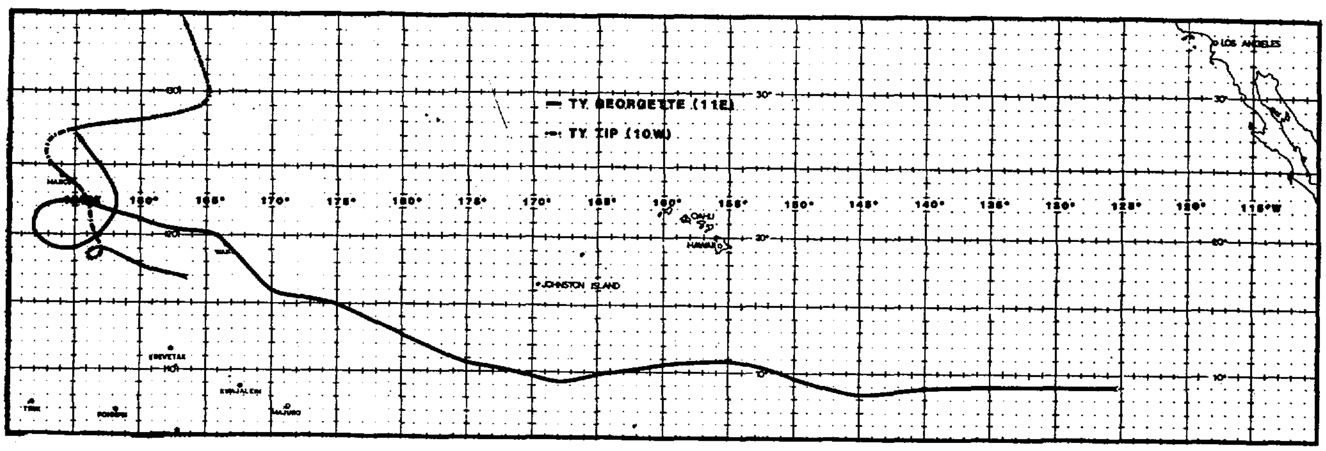


Figure 3-10-1. A composite plot of Tip's and Georgette's best tracks shows how closely linked the two were at the end of Georgette's long journey.

JTWC issued a TCFA on regenerated Tropical Storm Georgette (11E) at 090130Z based on analysis of satellite imagery which showed improved organization. A few hours later, JTWC followed with its first warning (#10 on the system), valid at 090600Z, when Georgette re-developed a central dense overcast.

The aircraft reconnaissance investigative mission into Georgette on 10 August at 0044Z discovered winds of 45 kt (23 m/sec) and a minimum sea-level pressure (MSLP) of 990 mb. Georgette continued to develop over the next 18-hours reaching minimal typhoon status by 101800Z. Aircraft reconnaissance confirmed this at 102135Z, reporting estimated maximum surface winds of 65 kt (33 m/sec) and a MSLP of 973 mb.

Georgette remained a typhoon for 36-hours, slowed in forward speed, and reverted to a tropical storm again after 120000Z (see Figure 3-10-2). This was apparently due to the proximity of a Tropical Upper-Tropospheric Trough cell to the north and increased vertical shear.

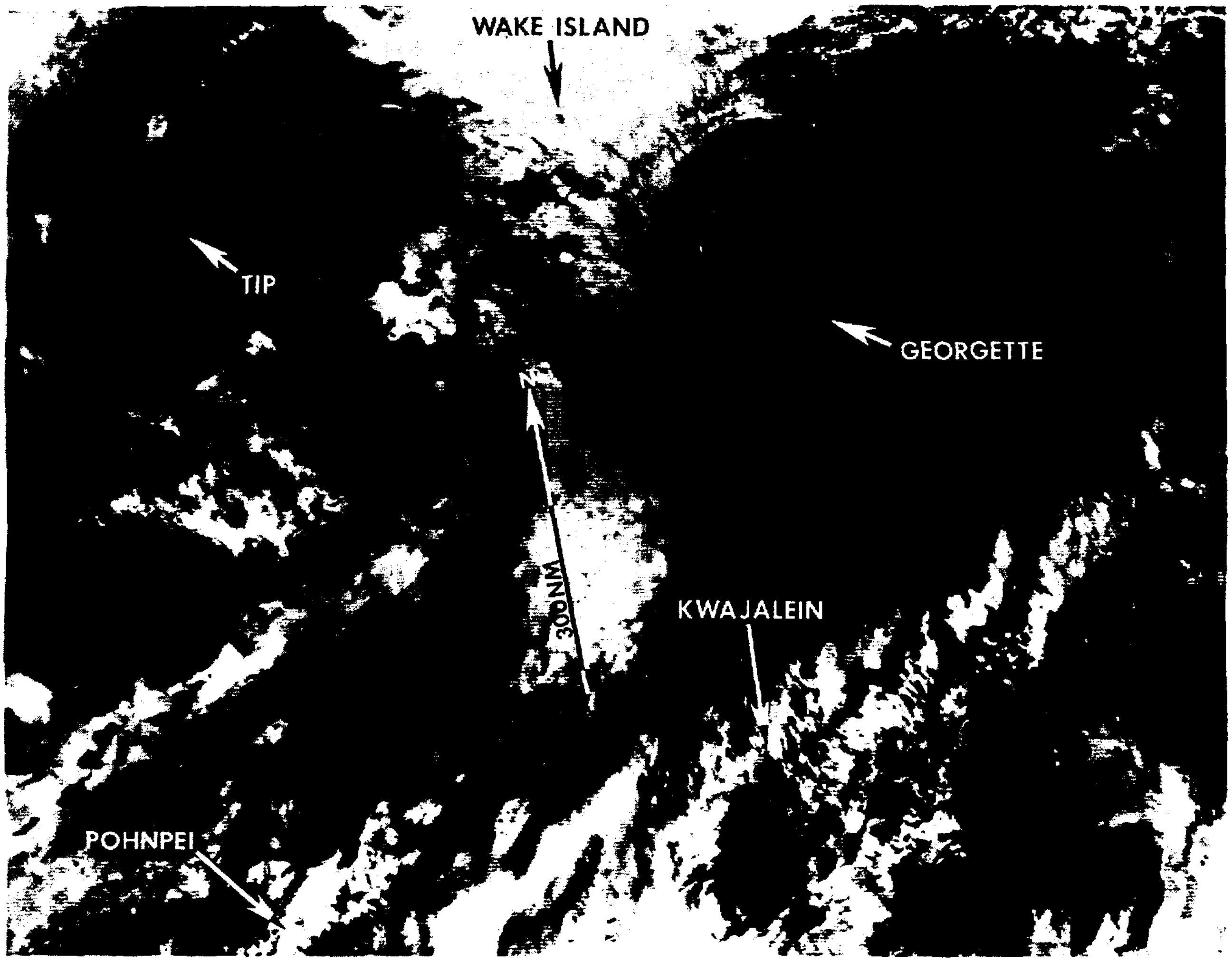


Figure 3-10-2. Georgette (to the east) was weakening as Tip was developing rapidly to its west (121059Z August DMSP infrared imagery).

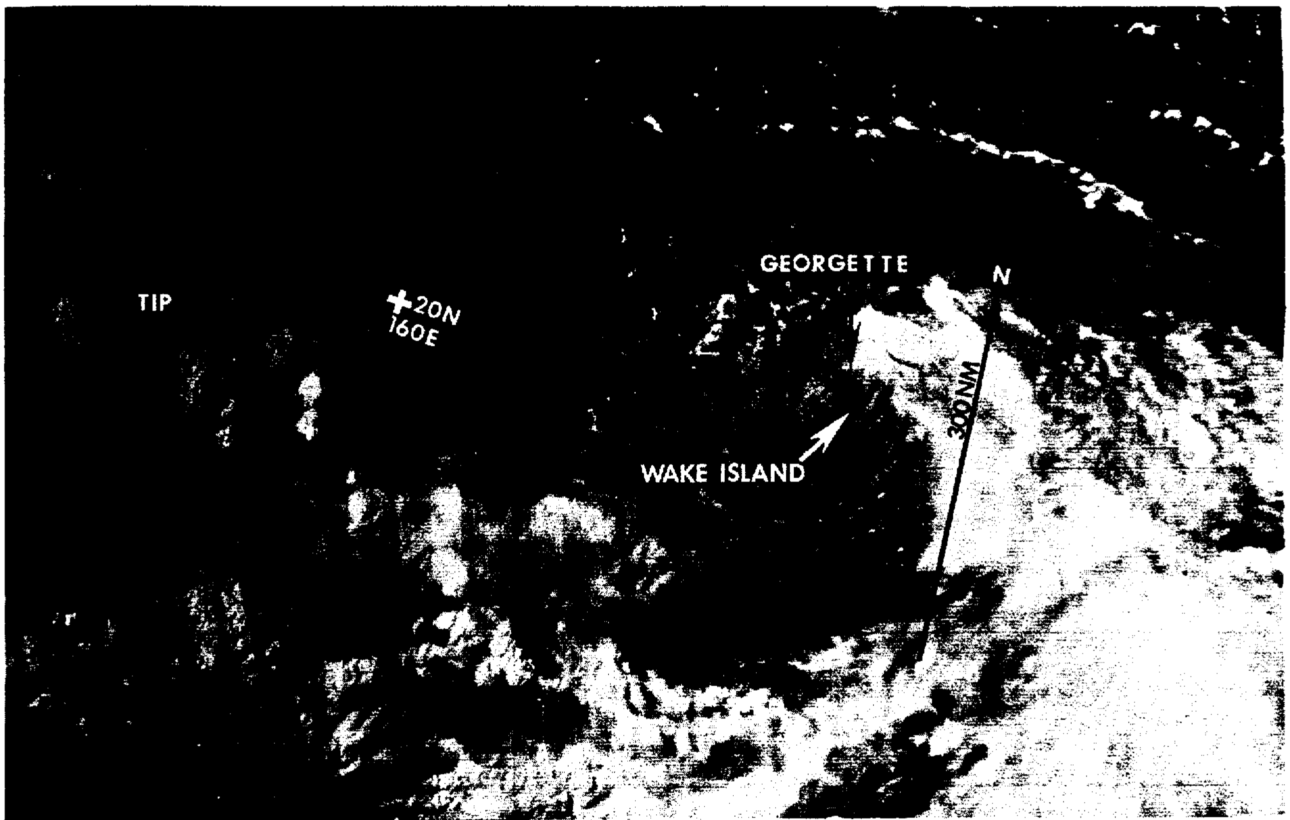


Figure 3-10-3. Georgette just after passing within 30 nm (56 km) to the north of Wake Island. Upper-level shear on the system from the west has exposed the low-level center. Tip, located to the west-southwest of Georgette, was just a few hours away from the first warning (130358Z August DMSP visual imagery).

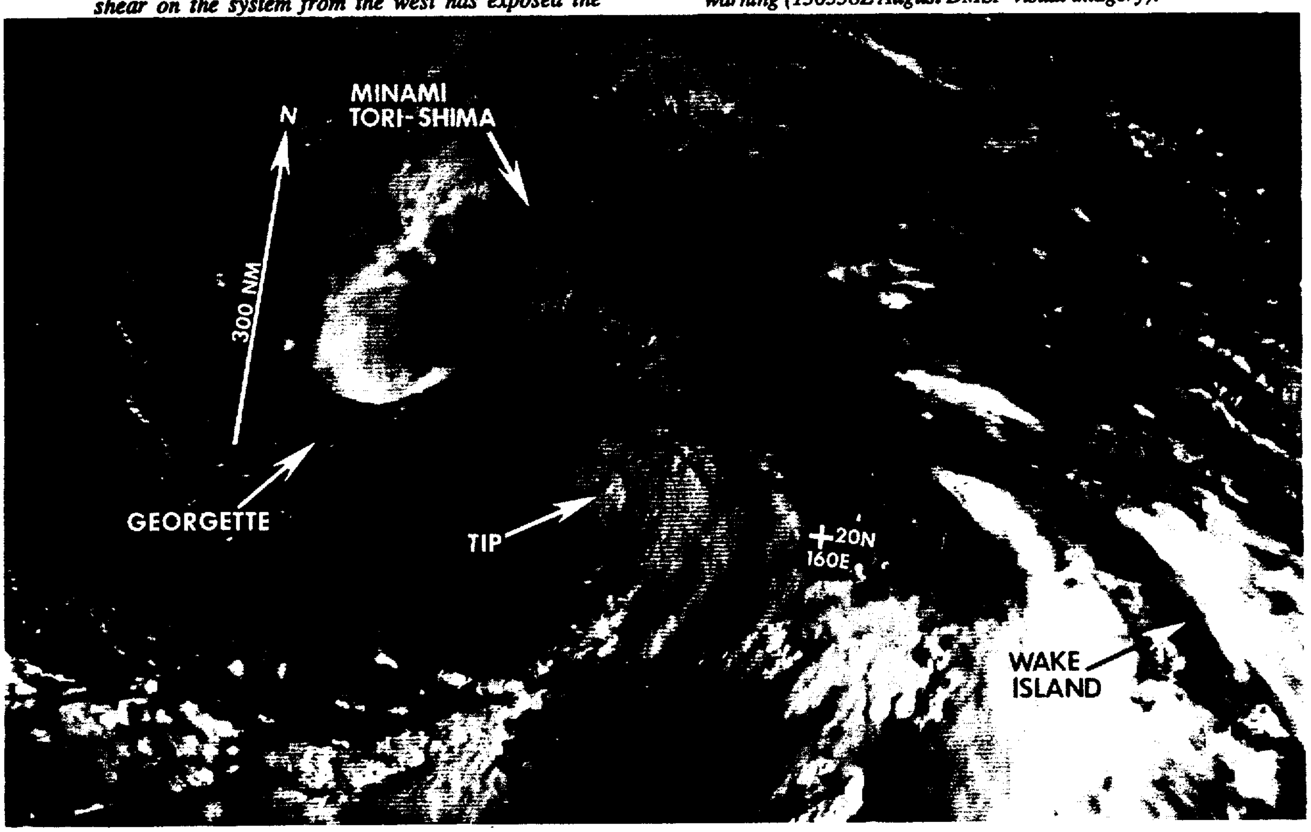


Figure 3-10-4. Tropical Storm Tip as it became the dominant system. Georgette was still a minimal tropical storm and its exposed low-level center was visible as it circled counterclockwise about Tip (142259Z August DMSP visual imagery).

Georgette continued moving toward the northwest, passing almost directly over Wake Island early on the 13th (see Figure 3-10-3). They received maximum sustained winds of 43 kt (22 m/sec) at 130101Z out of the north. No damage was reported by the seven Air Force personnel stationed there. Despite strong shear at upper-levels, it retained minimal tropical storm intensity until after it had circled completely around Typhoon Tip. Georgette weakened to tropical depression intensity for the last time on 15 August (see Figure 3-10-4). Georgette remained distinguishable from Tip for only a day longer (see Figure 3-10-5), then was absorbed into Tip's major convective inflow band.

Tip began early on 9 August as a tropical disturbance located 250 nm (463 km) southwest of Wake Island. The disturbance was placed on the ABPW PGTW by JTWC after it persisted for a day on satellite imagery. The first TCFA was issued at 110430Z on Tip based on an aircraft reconnaissance investigative mission that found a low-level circulation center with maximum winds of 20 to 40 kt (10 to 21 m/sec). The strongest winds were on the north side of the circulation associated with the maximum pressure gradient. The MSLP was 1001 mb.

The second TCFA was issued the next day (12 August) when aircraft reconnaissance did not find a closed circulation center but only a broad surface pressure trough with a MSLP of 998 mb. No substantial winds were noted and the system appeared

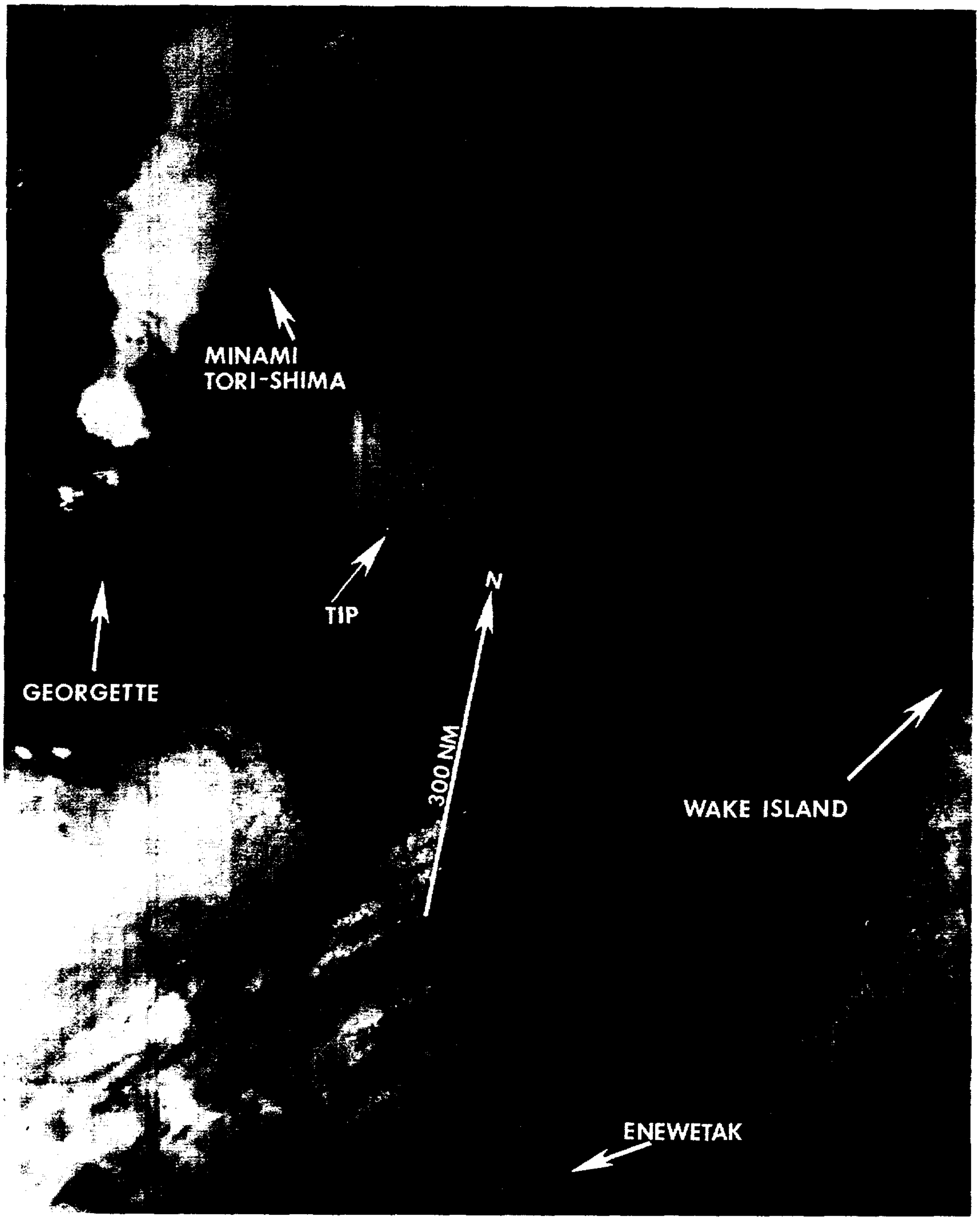


Figure 3-10-5. Tropical Depression 11E (Georgette) retains only its low-level circulation. All the heavy convective activity has become concentrated around Tropical Storm Tip (150336Z August DMSP visual imagery).

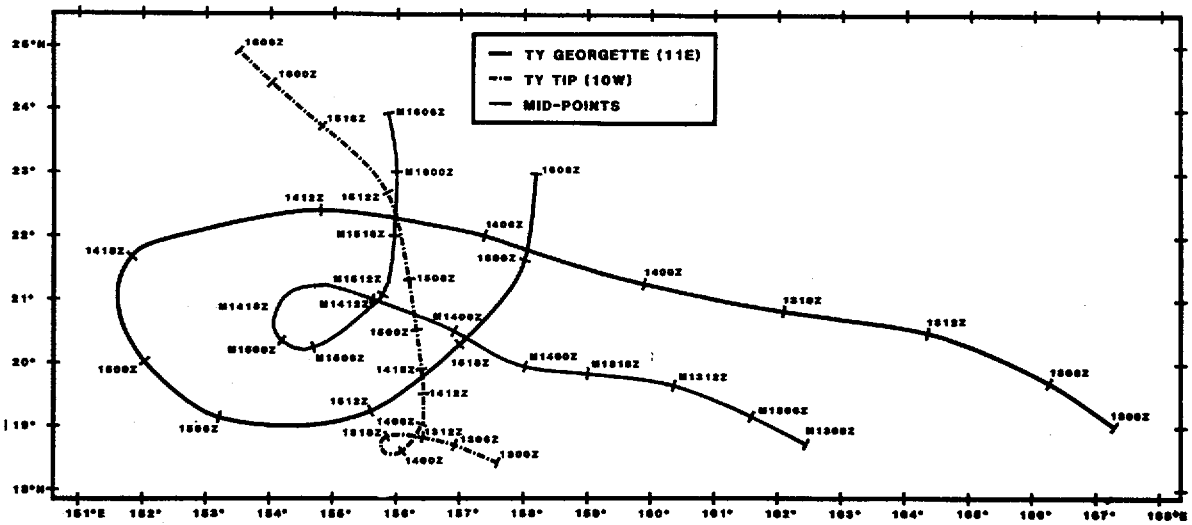


Figure 3-10-6. The binary interaction between Georgette and Tip. The plot of their respective best tracks and midpoints are shown between 130000Z and 160600Z August 1986.

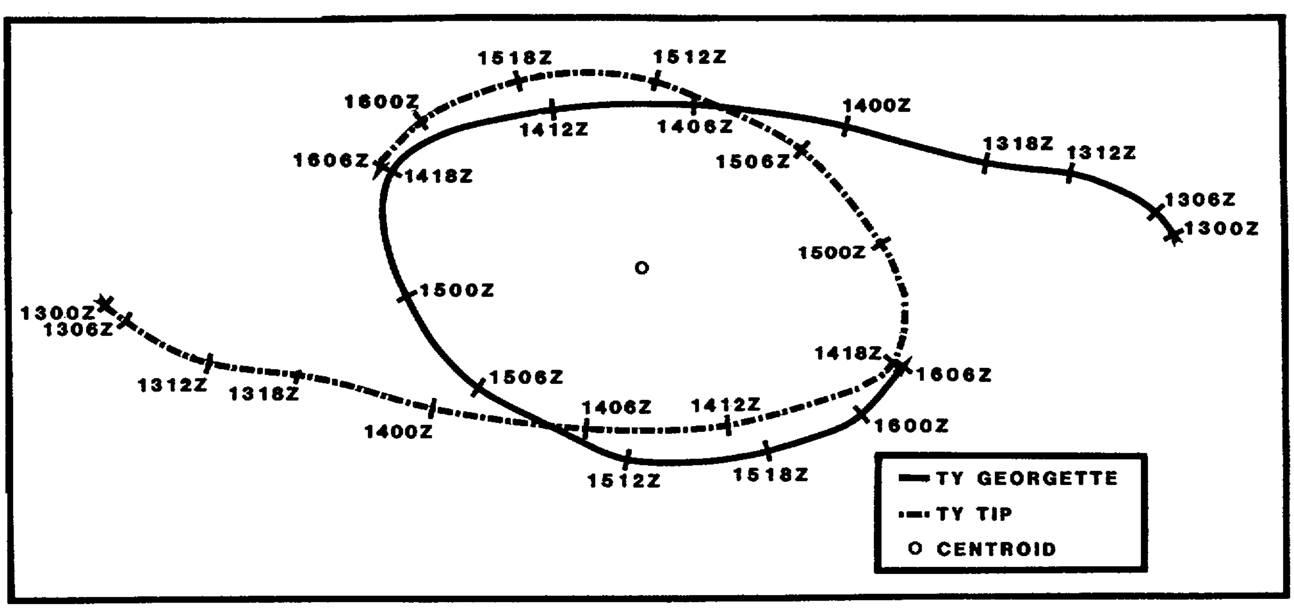


Figure 3-10-7. When the translational motion is removed from both Georgette and Tip, their distinctive center-relative counterclockwise movement about the centroid of their midpoints becomes apparent.

to be quasi-stationary, perhaps due to its proximity to Georgette.

The third TCFA was issued on 13 August without new aircraft reconnaissance information due to the lack of available reconnaissance assets. Later, after an aircraft reconnaissance investigative mission found winds of 50 kt (26 m/sec) and a MSLP of 987 mb, JTWC issued its first warning on Tip, valid at 130600Z. The same aircraft also fixed Georgette 160 nm (296 km) northwest of Wake Island (see Figure 3-10-3). The two tropical cyclones were 450 nm (833 km) apart at this time. At 131800Z, they were only separated by 400 nm (741 km) and it appeared that Tip was capturing the low-level inflow of Georgette and was becoming more intense.

A binary interaction occurred between Georgette and Tip with Georgette tracking west-northwestward and circling around Tip in a counterclockwise motion (see Figure 3-10-6). Initially, Tip was moving very slowly in the same direction, but it eventually did a small counterclockwise loop. Tip benefited from Georgette's passage to the north because it acted as a shield from the unfavorable upper-level shearing effect of the strong westerlies aloft. Removing the translational motion and plotting the relative motion of the two systems about the centroid of their midpoints (Figure 3-10-7) verifies the binary interaction as the pair circled one another in a broad elliptical path.

During the latter part of the binary interaction, as Tip was moving north-northwestward, it increased in intensity and in the process passed over Minami Tori Shima (formerly Marcus Island). At 160600Z, Tip peaked with 80 kt (41 m/sec), then turned to the right on the 17th and headed off toward the northeast (see Figure 3-10-8).

Tip transitioned to an extratropical cyclone on the 19th (see Figure 3-10-9) and eventually dissipated (4 days later) east of Japan. JTWC issued its final warning on the system at 190600Z. No reports of damage or fatalities were received on these two tropical cyclones.

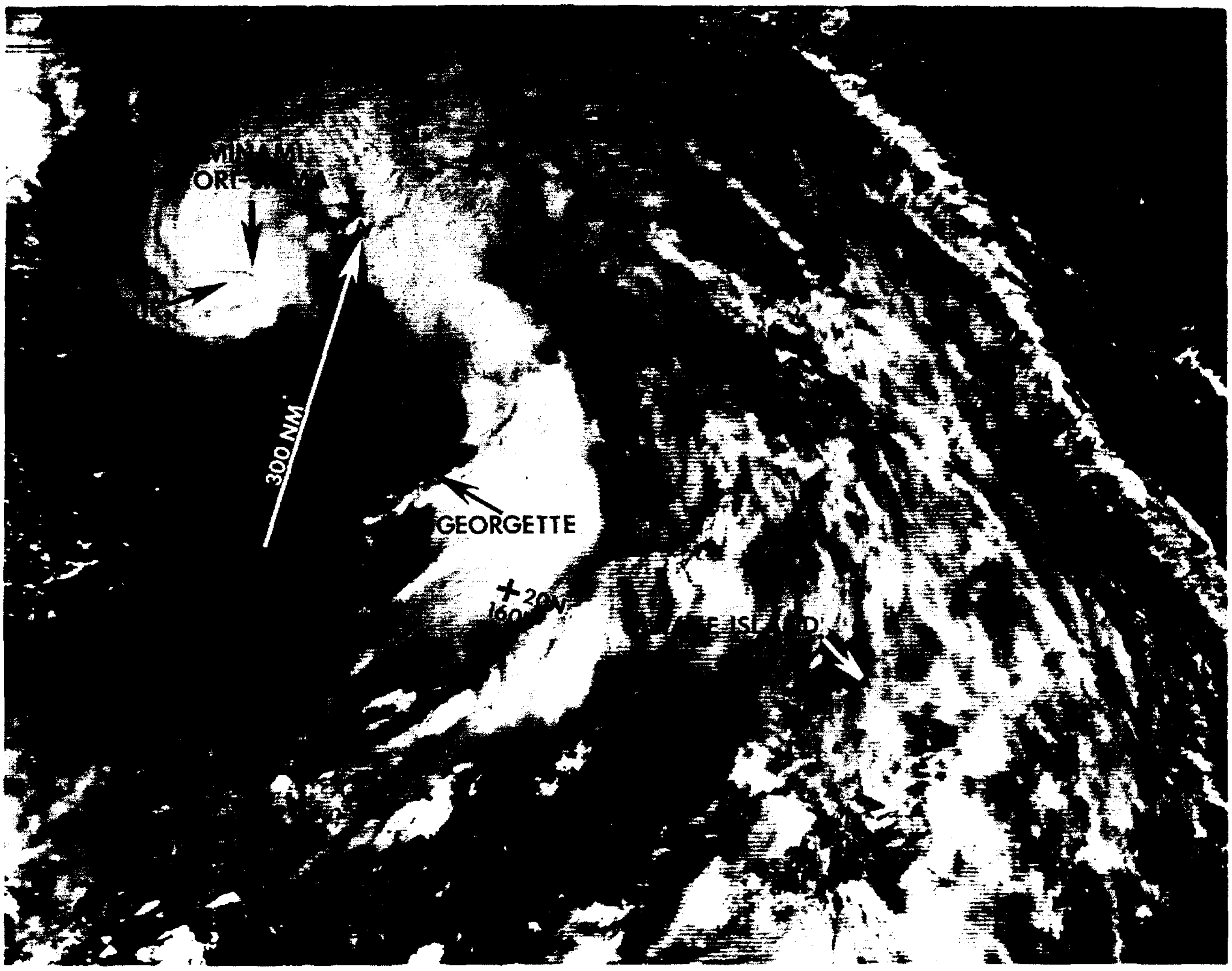


Figure 3-10-8. Typhoon Tip passing within 30 nm (56 km) to the northeast of Minami Tori Shima (formerly Marcus Island) (152239Z DMSP visual imagery).

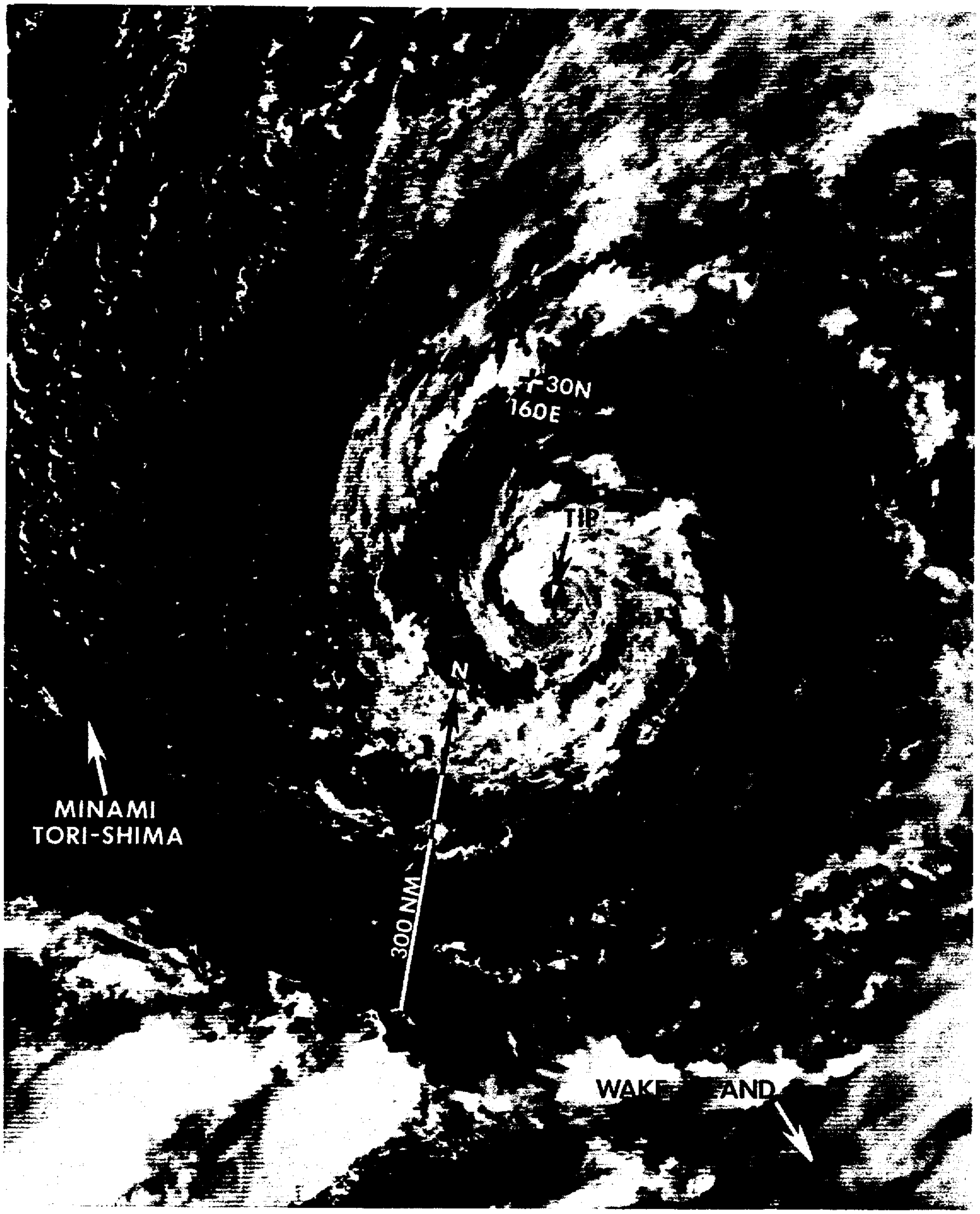
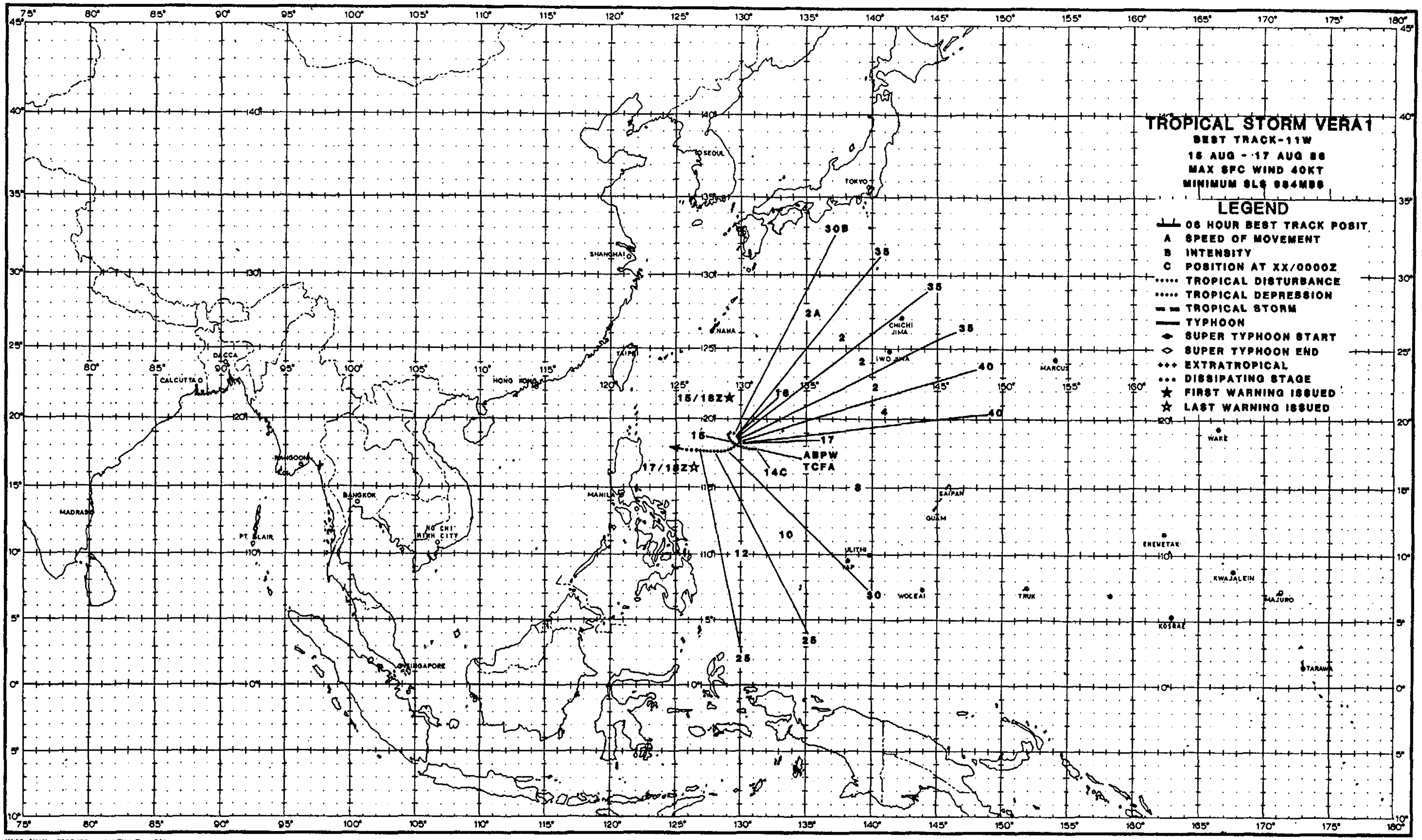


Figure 3-10-9. Tropical Storm Tip becoming extratropical. Note the wrapping of the relatively clear area around the center and the ragged appearance of Tip's central convection (182318Z August DMSP visual imagery).



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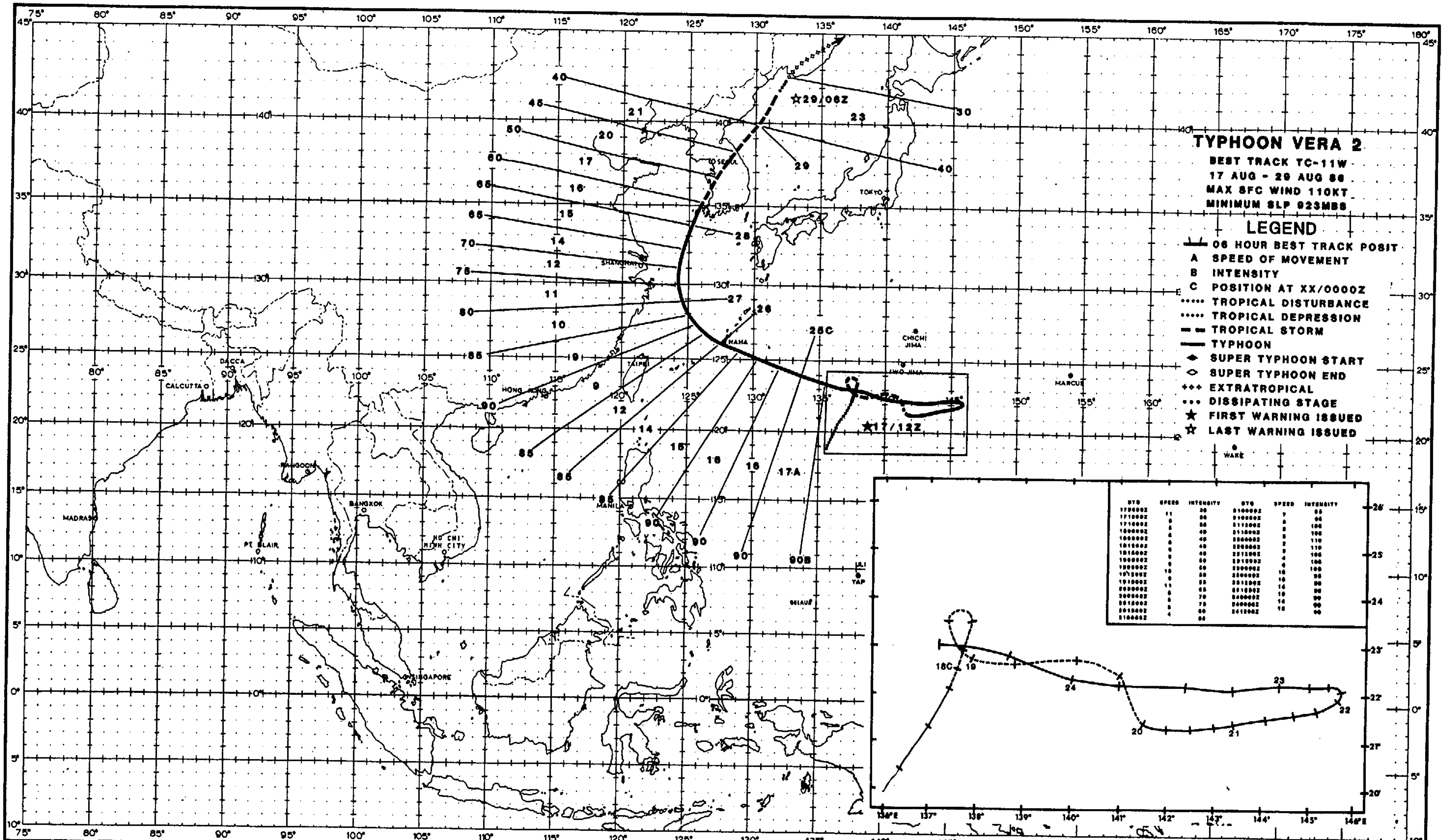


NOCC GUAM 3142/20 (NEW 5 - 80)

Typhoon Vera was another classic "monsoon depression" (see Tropical Storm Sarah (09W)) which formed in the most intense and extensive monsoon trough in the western North Pacific since 1974. Locating and forecasting the initial phases of Vera (from 14 to 18 August 1986) within this extensive trough presented unique problems for JTWC. Vera was relocated several times within the monsoon trough as the low-level flow attempted to stabilize around one circulation center. In post analysis, it was determined that Vera was actually two systems: the first (Vera #1) stabilized only briefly, reached tropical storm intensity then dissipated in the central Philippine Sea; the second (Vera #2) formed at the northeast periphery of the monsoon trough, over 360 nm (667 km) from Vera #1, developed slowly and reached typhoon intensity before crossing Okinawa and the Korean peninsula. The problems in locating and forecasting Vera's low-level circulation center were exacerbated by limited aircraft availability (due to other high priority missions for WC-130 aircraft and multiple tasking problems with Typhoons Tip (10W) and Georgette (11E)), sparse synoptic data and inconclusive satellite imagery.

Vera #1 developed on the heels of two typhoons, Tip (10W) and Georgette (11E). On 12 August, Georgette (11E) was moving west-northwestward and was located to the southeast of Wake Island. The onset of the intense and extensive monsoon trough associated with Georgette's inflow region was first noticed at that time, as southwesterly gradient winds of near 30 kt (15 m/sec) were observed at Yap (WMO 91413), Truk (WMO 91334) and Pohnpei (WMO 91348). Georgette (11E) was positioned at the eastern end of this trough (Figure 3-11-1), which extended from the Philippine Islands to the dateline. The onset of the

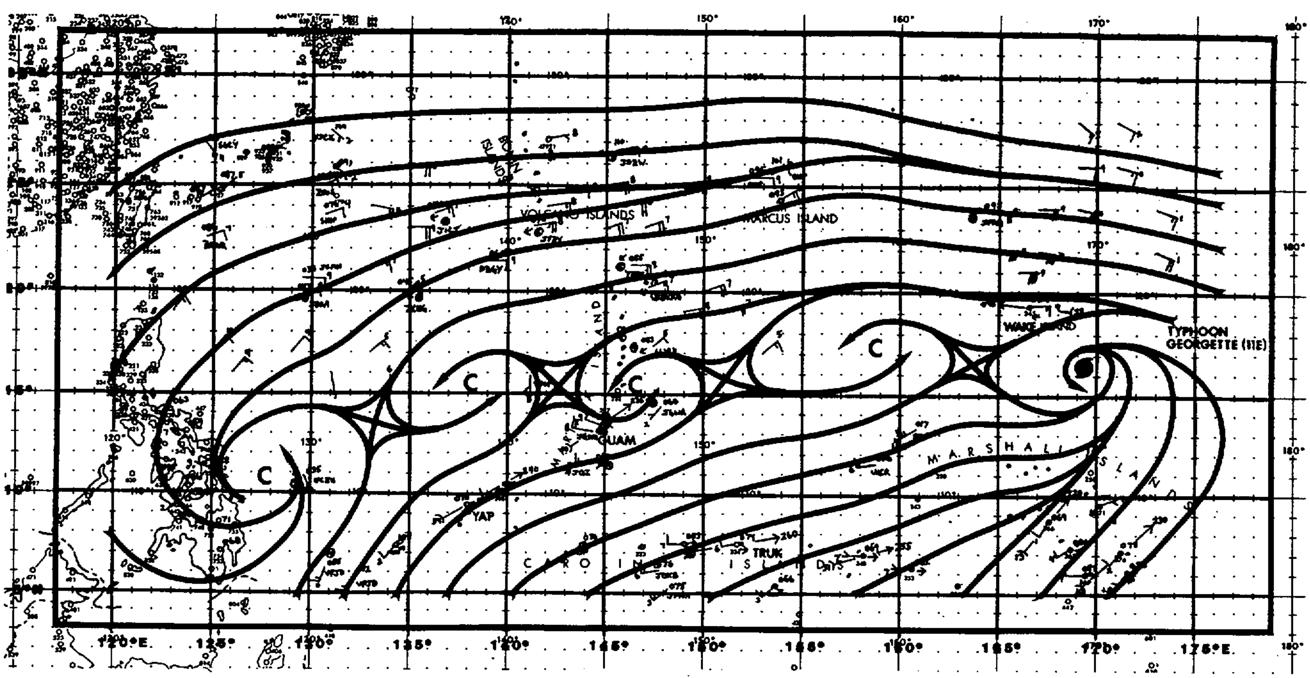


Figure 3-11-1. The surface/gradient analysis at 120000Z August showed the onset of the intense monsoon trough extending from the Philippine Islands to the dateline. Note the strong gradient wind reports at Yap (WMO 91413), Truk (WMO 91334), and Pohnpei (WMO 91348).

monsoon trough was accompanied by an extensive cloud maximum in the Philippine Sea (Figure 3-11-2) where Vera #1 formed. An interesting feature of the trough was the unusually low pressures, which were evident along the axis of the trough between 12 and 15 August. These pressures ranged from 996 to 1006 mb.

By the end of the second week of August gale force westerly winds were present in the southern Philippine Sea and transitory light and variable circulation centers formed along the trough axis. Satellite imagery provided little help in locating any of these circulation centers in the wind field due to the transitory nature of the central convection. Consequently, the circulation that eventually became Vera #1 was never mentioned on the Significant Tropical Weather Advisory (ABPW PGTW) as a suspect area, although several other areas in the monsoon trough were being reported on.

The first Tropical Cyclone Formation Alert (TCFA) was issued on 14 August at 0000Z. This was based on convection that had persisted for 12-hours and was colocated with an analyzed circulation center in the surface/gradient wind field. The TCFA was reissued at 150000Z, as satellite imagery indicated a slight increase in convective curvature. It appeared that the low-level flow was beginning to stabilize around an area located approximately 420 nm (778 km) south-southeast of Okinawa, Japan.

Figure 3-11-2. The area of intense convection that prompted the first TCFA on Vera #1. Note the extensive area of convection in the southwest monsoonal flow in the southern Philippine Sea (132119Z August DMSP visual imagery).

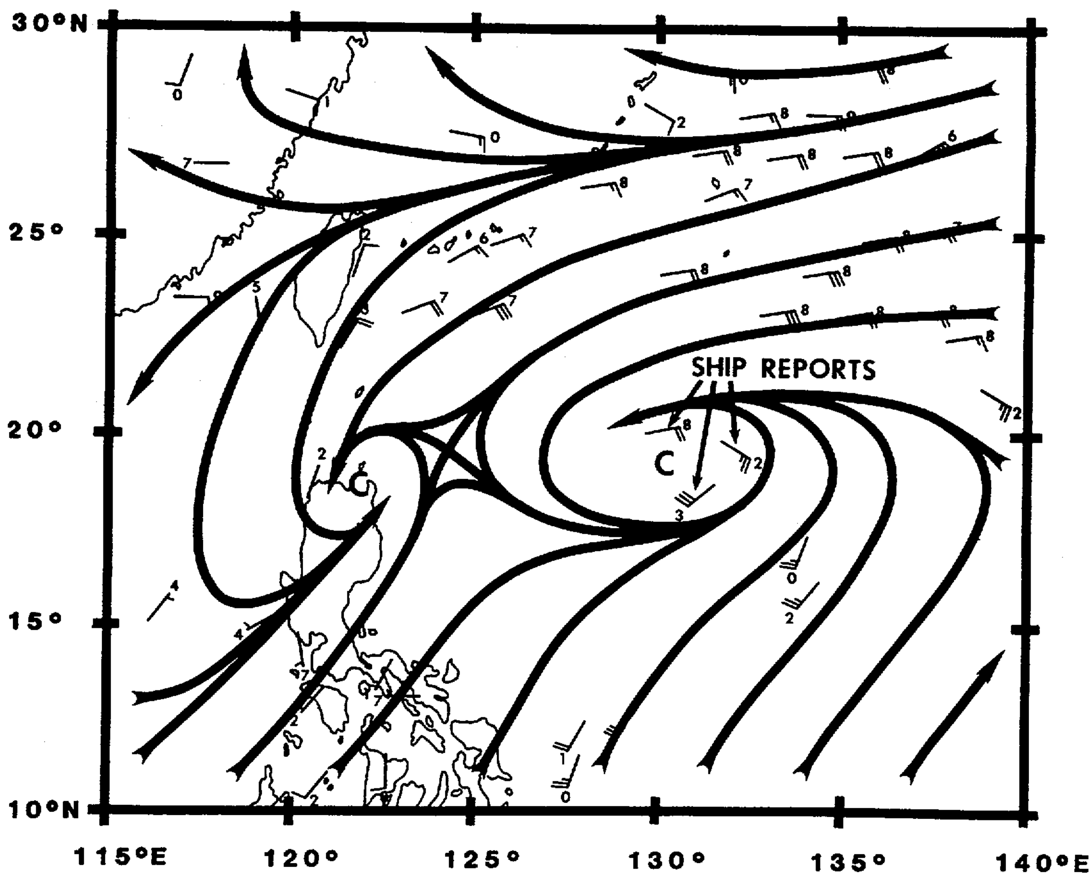


Figure 3-11-3. The 151200Z August ship reports which prompted first warning on Vera #1 at 151800Z August.

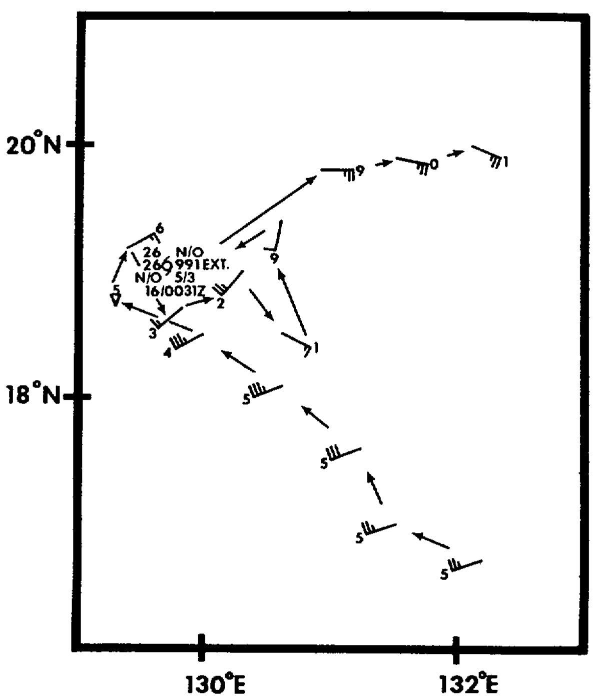


Figure 3-11-4. The August 16th daylight aircraft reconnaissance investigative mission into Vera #1 fixed the low-level circulation center.

At 151200Z, the first warning was issued on Vera #1 (the first system). This warning was prompted by three ship reports (Figure 3-11-3) that defined three quadrants of the 30 kt (15 m/sec) tropical depression. Twelve hours later, the aircraft investigative flight into Vera #1 found winds of 35 kt (18 m/sec) and a minimum sea-level pressure (MSLP) of 991 mb (Figure 3-11-4), confirming the ship report and justifying an upgrade to tropical storm intensity.

The forecast reasoning from 15 August to 17 August, prior to the formation of Vera #2 (the second system) to the northeast, was for Vera #1 to move slowly toward the west-northwest. This was based on the anticipation of the strengthening of the subtropical ridge to the north. However, Vera #1 remained confined to the lower troposphere and embedded in the monsoon trough. Aircraft reconnaissance at 850 mb (5000 ft (1524 m)) was unable to locate the circulation center during a nighttime fix mission on 16 August. At 162333Z, a daylight 1500 ft (457 m) fix mission indicated Vera #1 had moved about 60 nm (111 km) south-southeast of the the last fix mission. At that point Vera #1 was elongated east-west and relatively ill-defined. The surface/gradient analysis at 170000Z (Figure 3-11-5) indicated that the monsoon trough had elongated considerably with a large area of extremely low pressures (about 993 mb). At 171200Z the surface analysis indicated that Vera #1 was no longer evident.

Satellite imagery at 171240Z (Figure 3-11-6) indicated an apparent circulation center (Vera #2) southwest of Tip (10W), which was moving slowly northward and had become the dominant system in the monsoon trough. The analysis (Figure 3-11-5) was 12-hours prior to the formation of Vera #2 that was (perhaps mistakenly) maintained as Vera after being relocated more than 360 nm (667 km) to the east-northeast. The satellite data prompted the first warning on Vera #2 at 171200Z. The dramatic relocation was verified at 180716Z, when the first aircraft reconnaissance fix position in over 30-hours (Figure 3-11-7) confirmed the presence of the 50 kt (26 m/sec) system embedded in the monsoon trough.

The sudden and dramatic formation of Vera #2 caused many problems for the fleet customers as well as for the forecasters. In essence, Vera #1 had been forecast to move slowly toward the west-northwest for three days when the relocation occurred, placing the system 360 nm (667 km) to the east-northeast in a six hour period. Confusing and conflicting satellite imagery provided little insight into the location of the system during these stages. At 171200Z, Vera #2 was at tropical depression intensity and moving slowly northward. For the next three days, Vera #2 intensified slowly, moving erratically at first, and then slowly eastward within the monsoon trough. The intense trough was again asserting its influence on the system's track, as the remnants of Tip (10W) provided the "anchor" at the eastern end of the monsoonal flow. Vera #2 continued to move eastward with the monsoon west-southwesterlies until the 22nd, when it slowed and began to track northward.

The synoptic situation governing Vera #2's movement began to change on the 21st, when a small surface ridge appeared to be building to the north of Vera #2. This ridge continued to build, helped perhaps by increasing upper-level convergence to the east-northeast of Vera #2, enhancing subsidence in the upper troposphere and ridging at the surface.

Between 220000Z and 221200Z, Vera #2 turned northward, and then westward, as the low- to mid-level ridge became firmly established to the north. The shift in the steering flow is evident in the change in the 700 mb Numerical Variational Analysis (NVA) streamline analysis between 220000Z and 221200Z (Figures 3-11-8 and 3-11-9). Apparently, the mid-level trough associated with the remnants of Tip (10W) had completely disappeared by 221200Z and was replaced by ridging northeast of Vera #2. This ridge provided the steering flow until Vera #2's recurvature on 27 August. Vera #2 reached its maximum intensity of 110 kt (57 m/sec) and MSLP of 923 mb on 21 August, just prior to turning westward toward Okinawa.

Vera #2 continued to move west-northwestward from the 22nd through the 26th, passing directly over the island of Okinawa late on the 25th (Figure 3-11-10). The forecast had provided those on Okinawa with 66-hours of warning before the closest point of approach (CPA) occurred. All aircraft and ships had been evacuated, sortied, or secured long before Vera #2 hit with maximum sustained winds (over water) of 85 kt (44 m/sec).

The recurvature and extratropical transition phase of Vera #2's track began on 26 August. Upon reaching the western periphery of the subtropical ridge, Vera #2's movement had slowed to 9 kt (17 km/hr) and turned northwestward at approximately 260600Z. Vera #2 turned northward at about 270000Z and passed 160 nm (296 km) east of Shanghai 12-hours later. After passing east of Shanghai, Vera #2 began to accelerate north-northeastward. By the 28th, the tropical cyclone had lost its connection with the low-level monsoonal westerlies and weakened to 60 kt (31 m/sec). Figure 3-11-11 shows Vera #2 just prior to landfall near Kunsan AB, Republic of Korea, with a large cirrus shield to the north of the exposed low-level circulation, indicative of a tropical cyclone transitioning into an extratropical system. Vera #2 cleared the Korean peninsula at 281800Z with an intensity of only 45 kt (23 m/sec) and continued accelerating northeastward. It completed extratropical transition at 290600Z in the Sea of Japan.

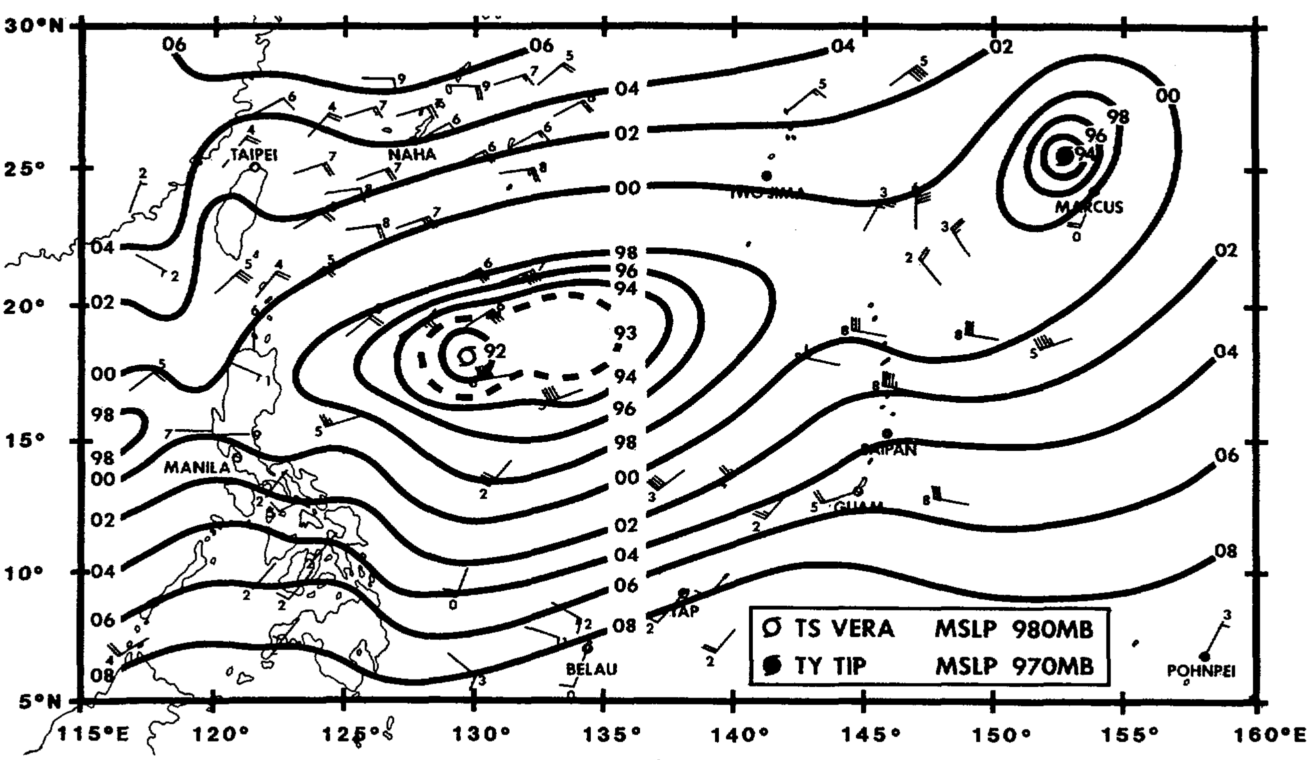


Figure 3-11-5. The surface/gradient analysis at 170000Z (12-hours prior to the formation of Vera #2). Note the elongated trough to the east and west of Vera #1.

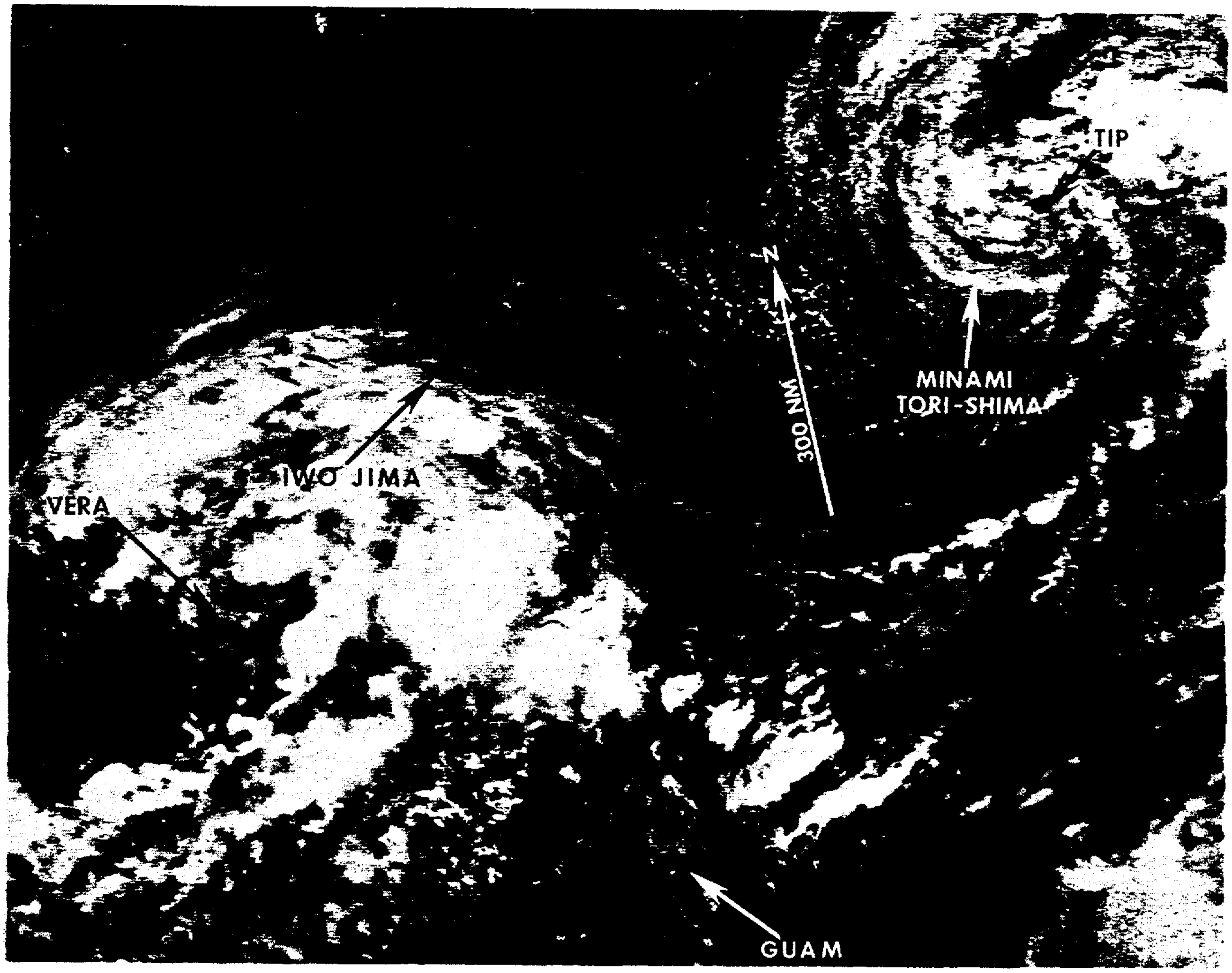


Figure 3-11-6. Typhoon Tip and the early stages of Vera #2 (171240Z August DMSP visual imagery).

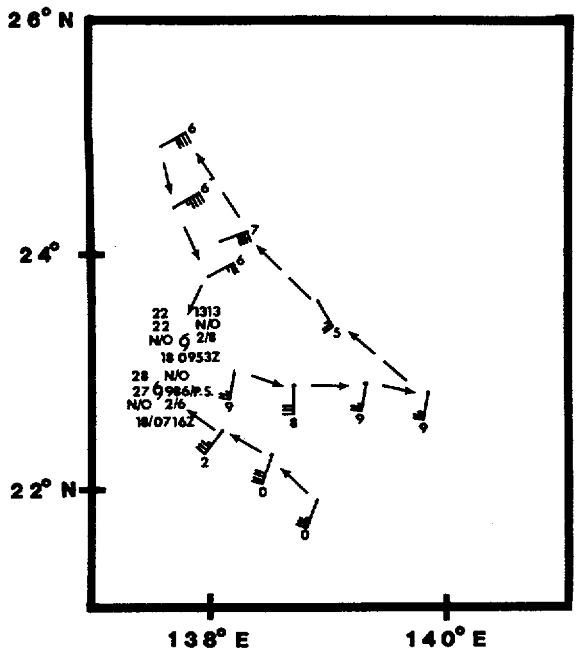


Figure 3-11-7. First aircraft reconnaissance fix mission after relocation to Vera #2 (180716Z).

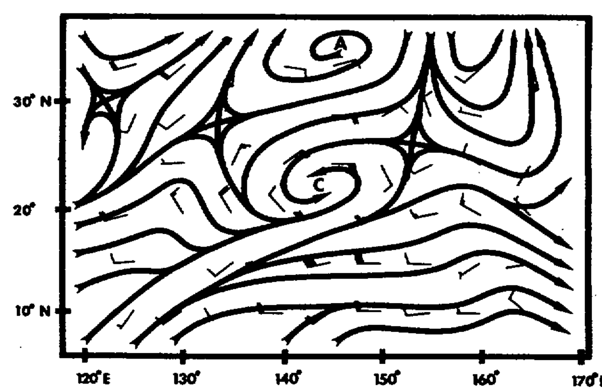


Figure 3-11-8. The 220000Z August 700 mb NVA analysis showing the trough (associated with the remnants of Typhoon Tip (10W)) to the northeast of Vera #2.

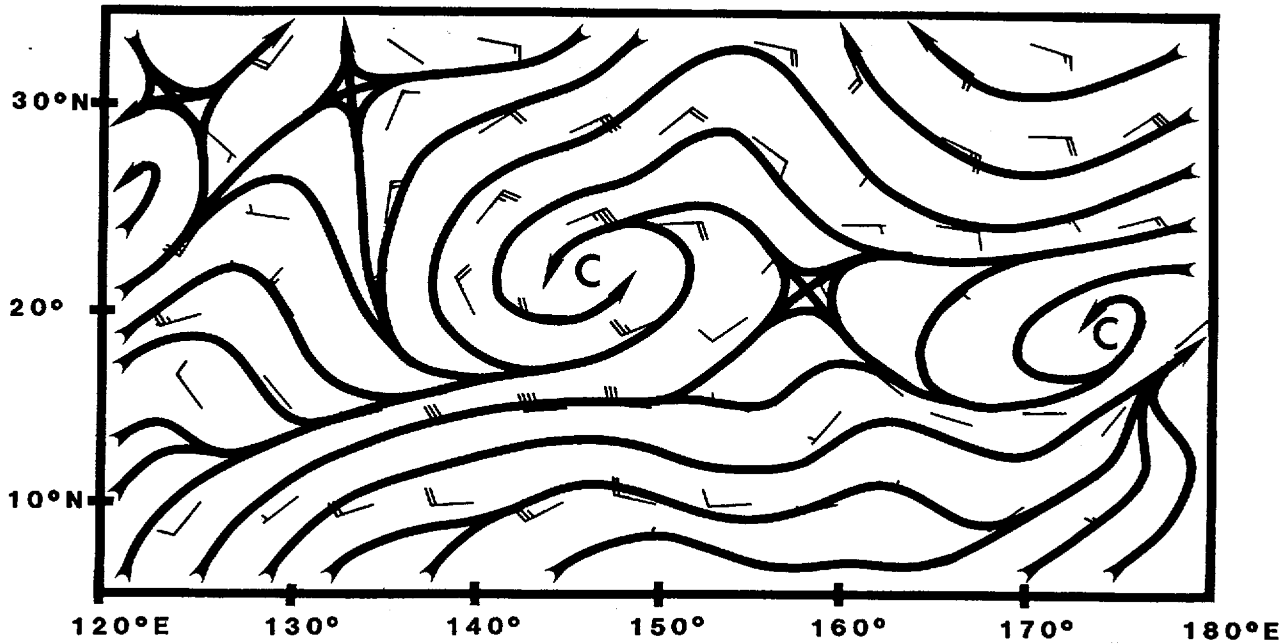


Figure 3-11-9. The 221200Z August 700 mb NVA analysis showing a ridge (in place of the trough 12-hours earlier) north and northeast of Vera #2.

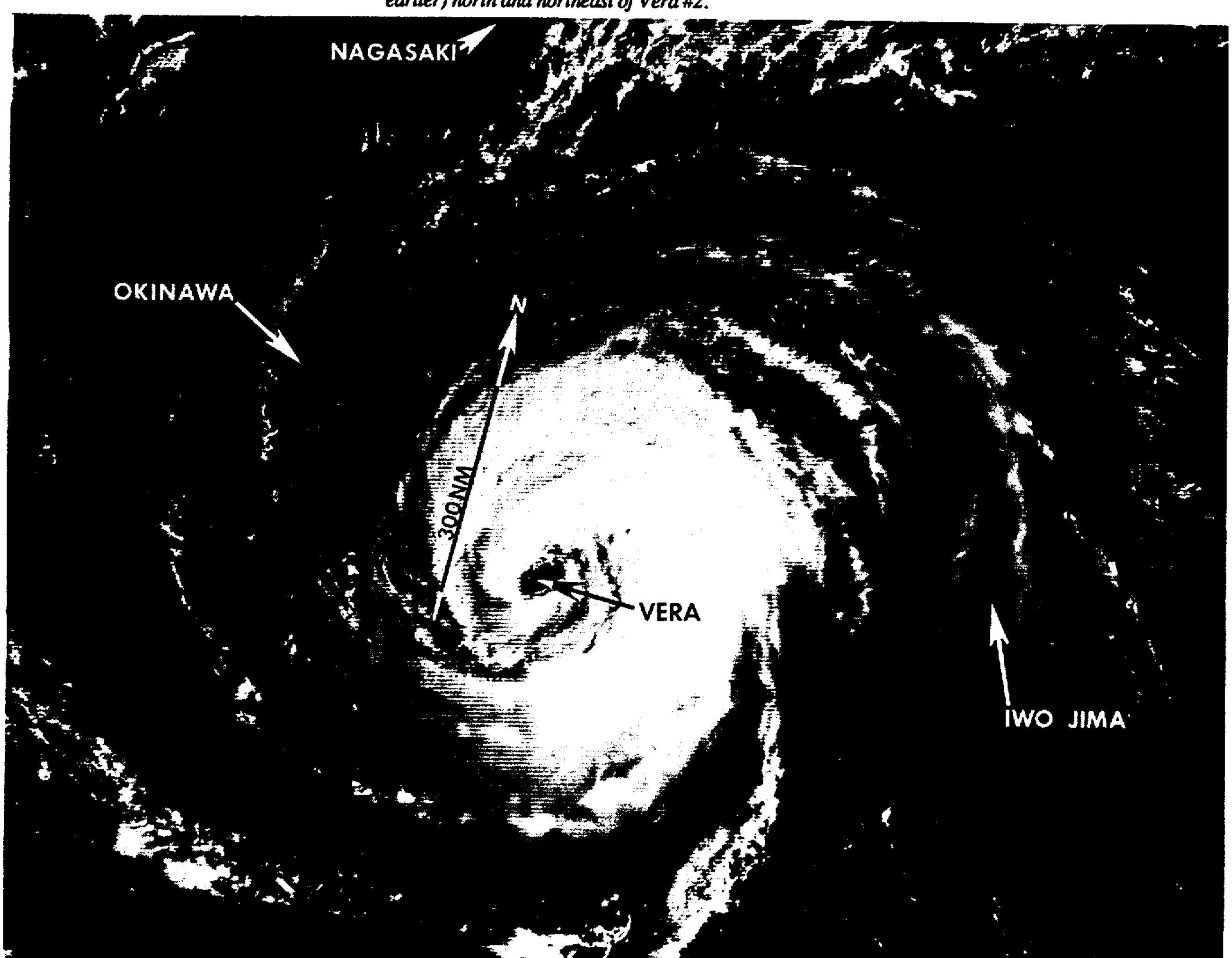


Figure 3-11-10. Vera #2 at typhoon intensity as it approached Okinawa (250039Z August DMSP visual imagery).

In addition to the problems of finding and forecasting the initial low-level center, Vera #2 caused considerable damage and loss of life. It severely impacted civilian shipping and military operations at sea. Okinawa, in contrast, because of the early warning provided, experienced only slight damage; mostly to power lines for private homes. One fisherman was killed. Kadena AB recorded peak wind gusts of 84 kt (43 m/sec). High seas, however, placed several ships at sea in distress. In Shanghai, seven people were killed and 28 injured when Vera #2 passed 160 nm (296 km) east of the city. The New China News Agency (NCNA) reported more than 500 homes were destroyed and 3,000 emergency workers were recalled to restore electrical supplies and to ensure dikes along the Huangpu river and the coast were secure. NCNA also reported that more than 3,000 vessels sought shelter as Vera #2 approached. On the Island of Cheju, 28 houses were destroyed, leaving 50 people homeless. In South Korea, six people were killed and over one million dollars worth of damage was reported. The most extensive damage to U.S. military facilities was reported at Taegu AB, where more than 75 trees were felled and power lines were downed. The roofs of several buildings were blown away.

In retrospect, Vera underscores the difficulty of positioning and forecasting tropical cyclones that form in strong monsoonal troughs. In addition, the eastward movement of Vera #2 for three days was an interesting anomaly that was perhaps influenced by the intense monsoon trough that extended throughout the entire western North Pacific for most of August.

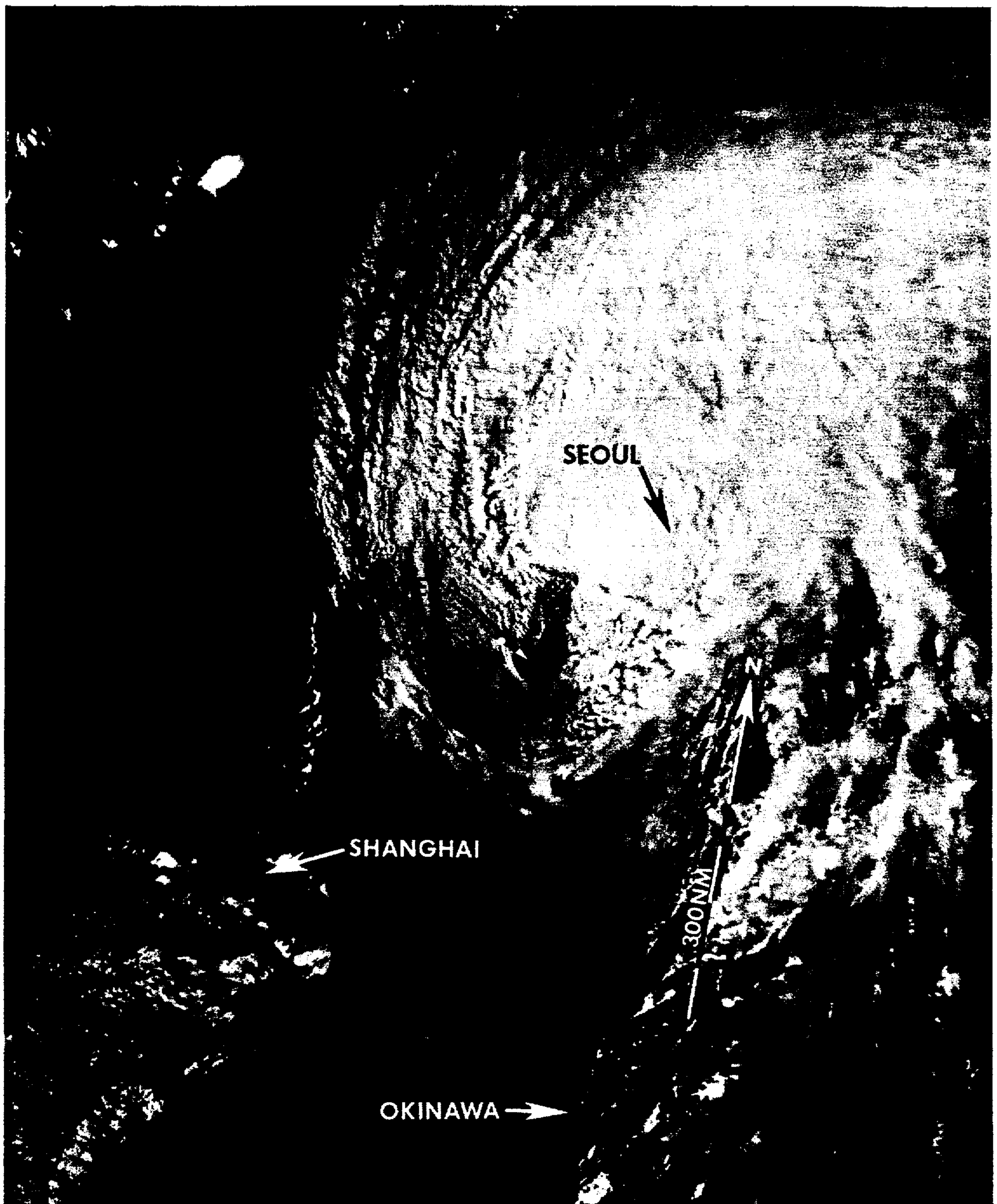
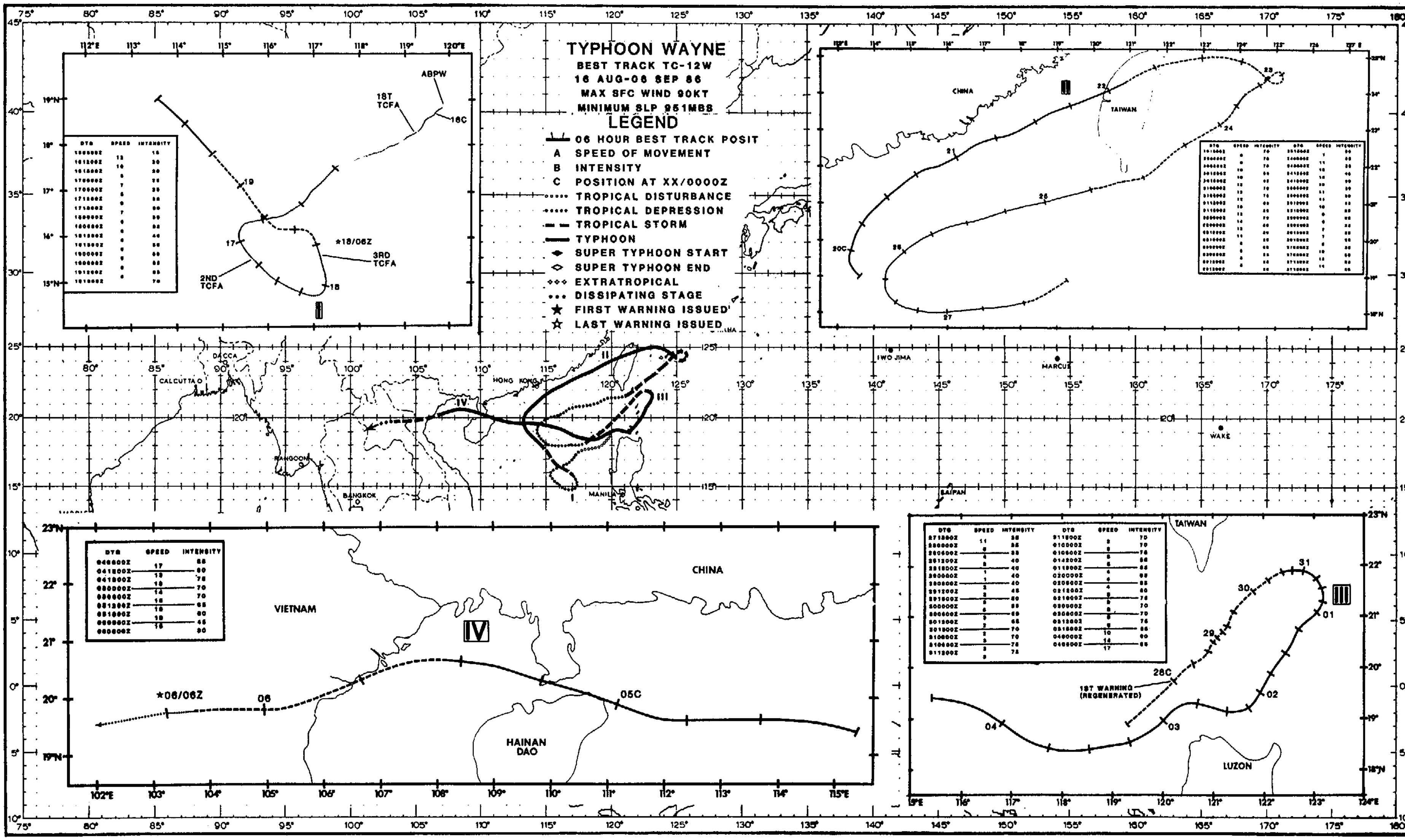


Figure 3-11-11. Vera #2 in the beginning stages of extratropical transition just prior to landfall near Kunsan AB, Republic of Korea (280621Z August NOAA visual imagery).



NOCC GUAM 3142/20 (NEW 5 - 80)

Typhoon Wayne was one of the longest-lived tropical cyclones in the 28-year history of the Joint Typhoon Warning Center (JTWC). Wayne had more warnings (67) issued on it than any other tropical cyclone of 1986. Another unusual fact concerning Typhoon Wayne was that it never fully emerged from the monsoon trough. Due to its highly atypical track, Wayne caused significant forecasting problems for JTWC.

Wayne was a small system that remained in the northern South China Sea and the western Philippine Sea throughout its entire life. Its best track includes three loops and a figure eight. To further complicate matters, Wayne also dissipated and then regenerated while still over tropical waters.

During the middle of August, the monsoon trough was well established in the western North Pacific and the South China Sea. Between 15 and 20 degrees North Latitude, it extended from central Vietnam eastward to Wake Island. Stronger than normal low-level westerlies equatorward of the trough axis were characteristic of the monsoon trough throughout the month of August and into early September. North of the monsoon trough, the subtropical ridge was also well established.

On August 15th, a small area of persistent convection moved westward across the island of Luzon into the South China Sea. Synoptic data at 150000Z and 151200Z indicated a surface circulation with 20 kt (10 m/sec) winds and a minimum sea-level pressure (MSLP) of 1002 mb. These data prompted JTWC to reissue the Significant Tropical Weather Advisory (ABPW PGTW) at 152100Z. Over the next two to three days, the disturbance moved southwestward and increased in organization. Three Tropical Cyclone Formation Alerts (TCFAs) were issued at 0400Z on the 16th, 17th and 18th of August to advise customers of the good potential for development of a significant tropical cyclone in the area.

After receiving aircraft reconnaissance reports of 40 kt (21 m/sec) and a MSLP of 985 mb at 180724Z (Figure 3-12-1), the first warning was issued on

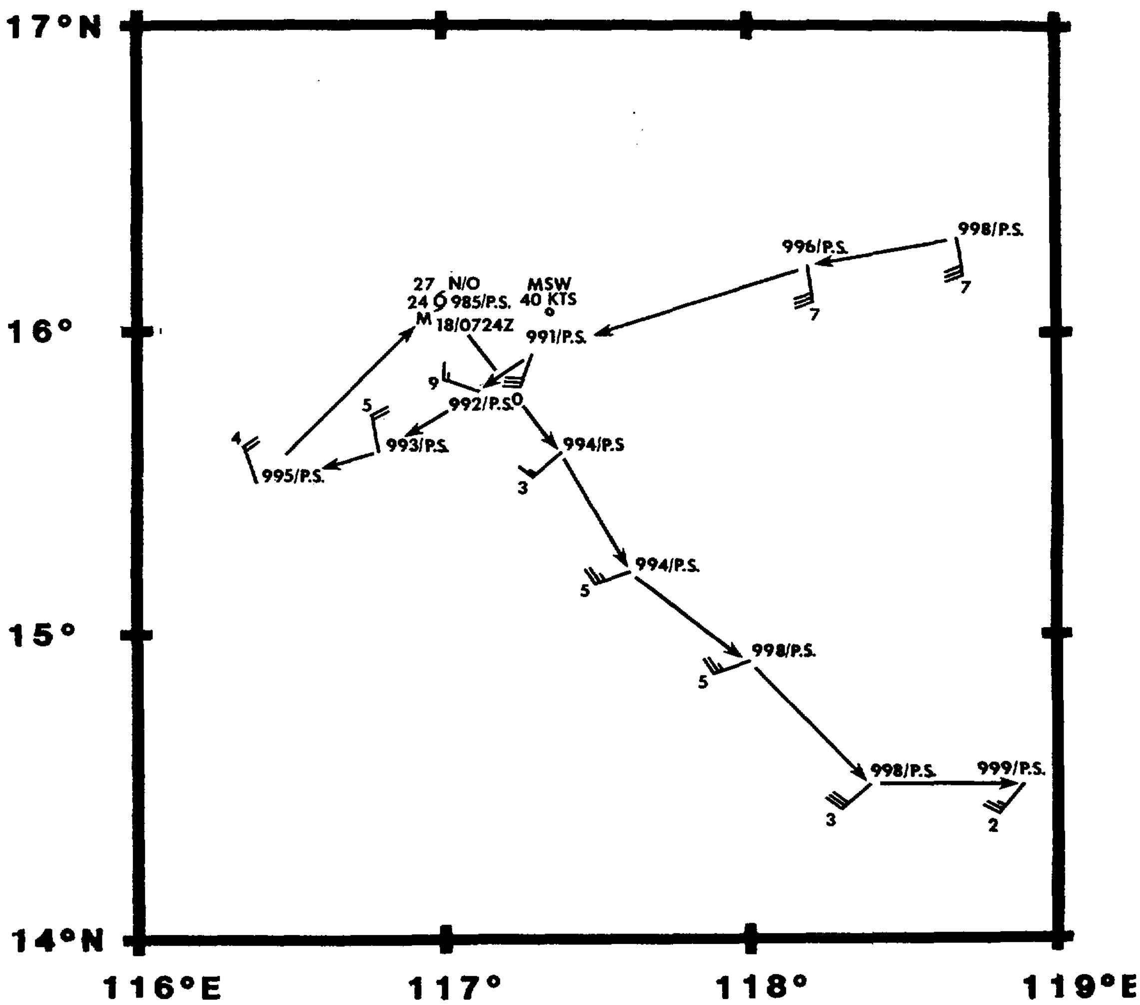


Figure 3-12-1. Aircraft reconnaissance investigative mission located maximum surface winds of 40 kt (21 m/sec) and a minimum sea-level pressure of 985 mb at 180724Z.

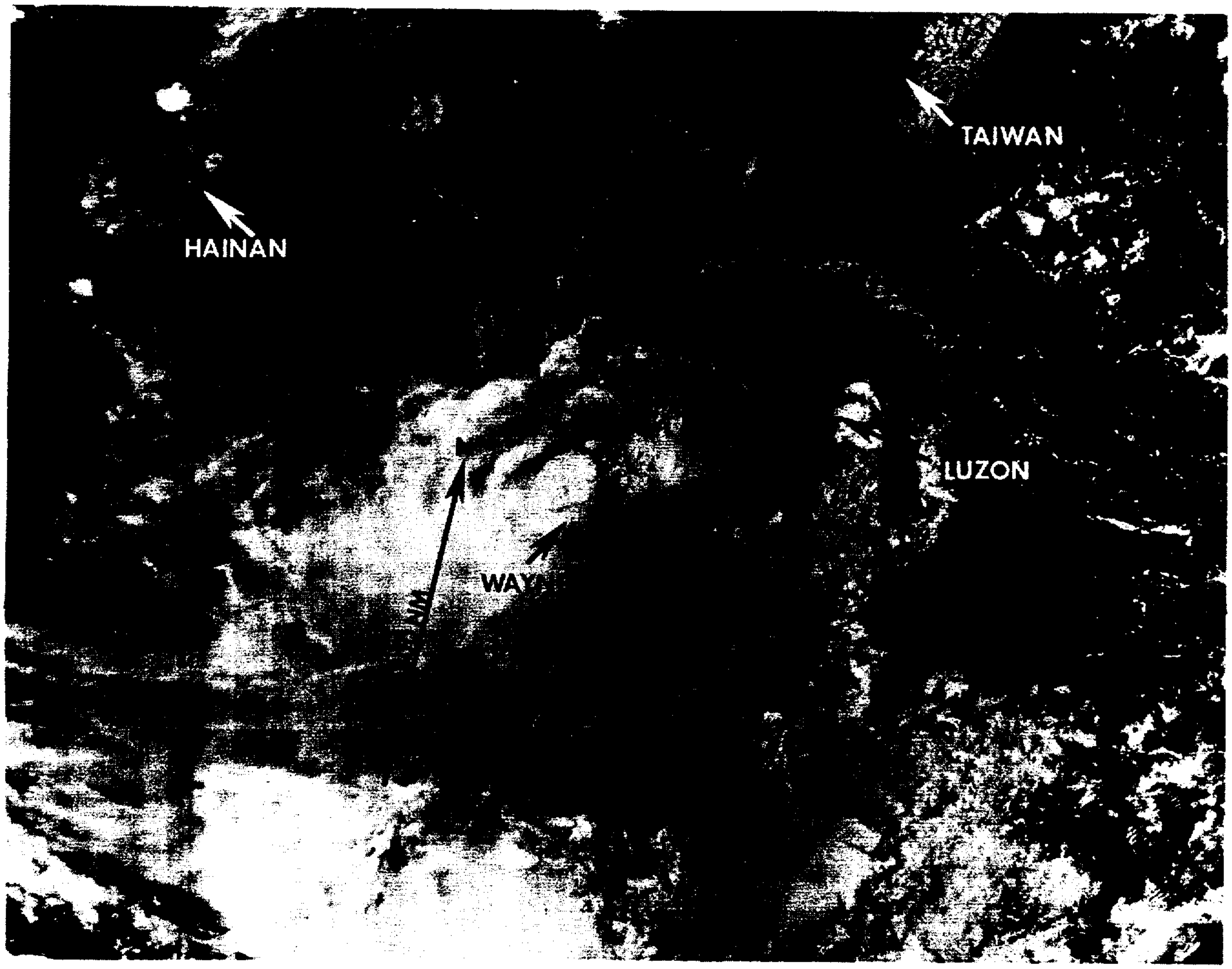


Figure 3-12-2. Wayne shortly before the aircraft reconnaissance mission (Figure 3-12-1) and first warning (180628Z August NOAA visual imagery).

Tropical Storm Wayne (Figure 3-12-2) valid at 180600Z.

Over the next two days, the synoptic scale monsoon trough shifted to the north about five degrees. Wayne responded by moving northwestward also. Throughout this period of position readjustment, gradual development brought Wayne to typhoon intensity at 190600Z. Meanwhile, a weak mid-latitude trough began to deepen and move eastward across mainland China toward the East China Sea. At 200000Z, this trough, and associated front, extended across the Yellow Sea southward to the southeast coast of China. Also, at 200000Z, Wayne assumed a northeastward track towards Hong Kong and the south coast of mainland China. Hong Kong's radar, at 202104Z (210504H Hong Kong local time) digitally

digitally depicted the rainbands surrounding the eye (Figure 3-12-3) as Wayne passed to the south and east. Another view shows the eye of the typhoon as it was remotely sensed, five-hours later, 450 nm (833 km) from space (Figure 3-12-4). On 22 August, Typhoon Wayne moved northeastward across northern Taiwan and weakened to tropical storm intensity after interacting with Taiwan's rugged mountains. In the meantime, Typhoon Vera (11W) had become the dominant system in the Philippine Sea and began moving rapidly toward the west-northwest. On the 24th, Wayne had moved rapidly west-southwestward and through the Luzon Strait (for the first time) in response to the northeasterly steering flow associated with the subtropical ridge. As Vera (11W) approached, Wayne decreased significantly in intensity and central convection. Increased vertical shear and subsidence associated with Vera (11W) stripped Wayne of its supporting central convection. As a result, only a small low-level exposed circulation center remained. A final warning on Wayne was issued at 250600Z, but JTWC continued to monitor the disturbance for possible redevelopment.

As Vera (11W) moved northward (261200Z), the remains of Wayne became entrained in Vera's extensive low-level inflow and began to move east-northeastward

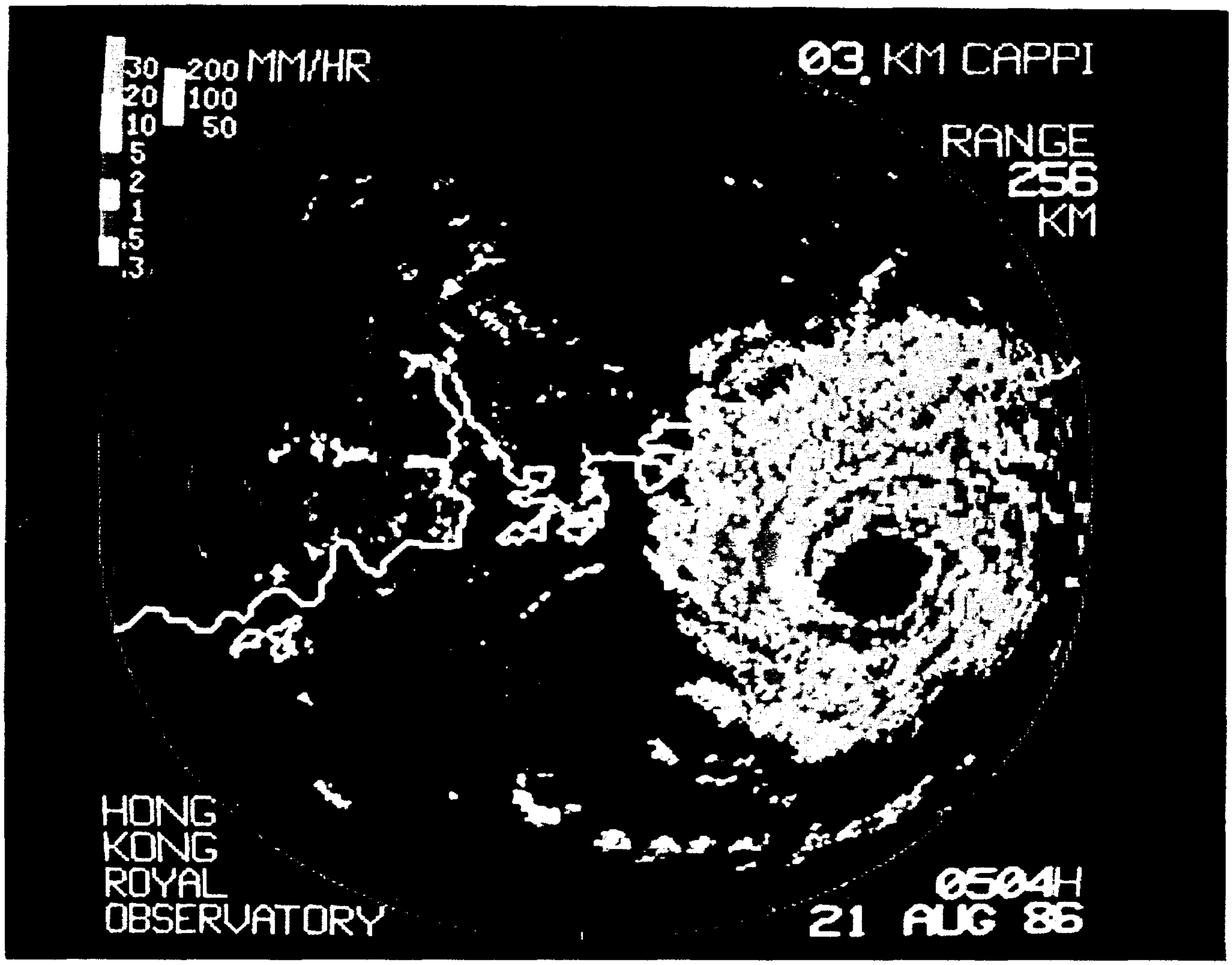


Figure 3-12-3. Digitized radar presentation of Typhoon Wayne at 202104Z (Photograph courtesy of the Hong Kong Royal Observatory).

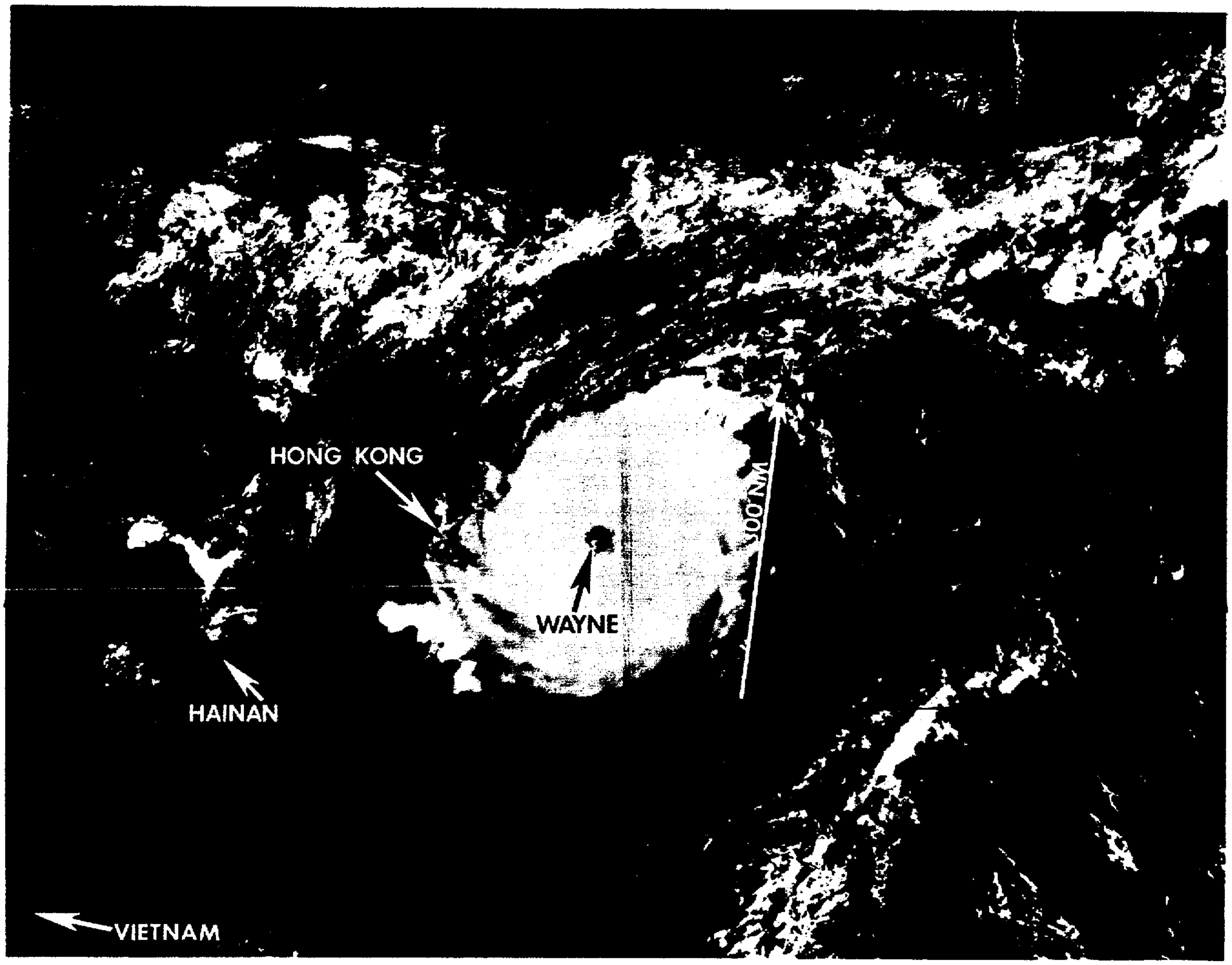


Figure 3-12-4. The eye of Typhoon Wayne. The band of cloudiness associated with the weak front, extending east-west and just to the north of the typhoon (210200Z August DMSP visual imagery).

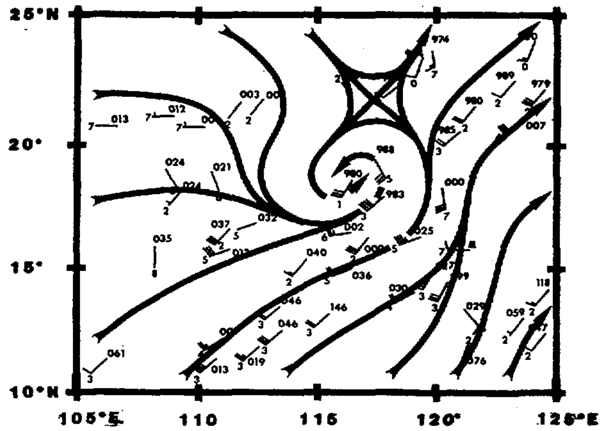


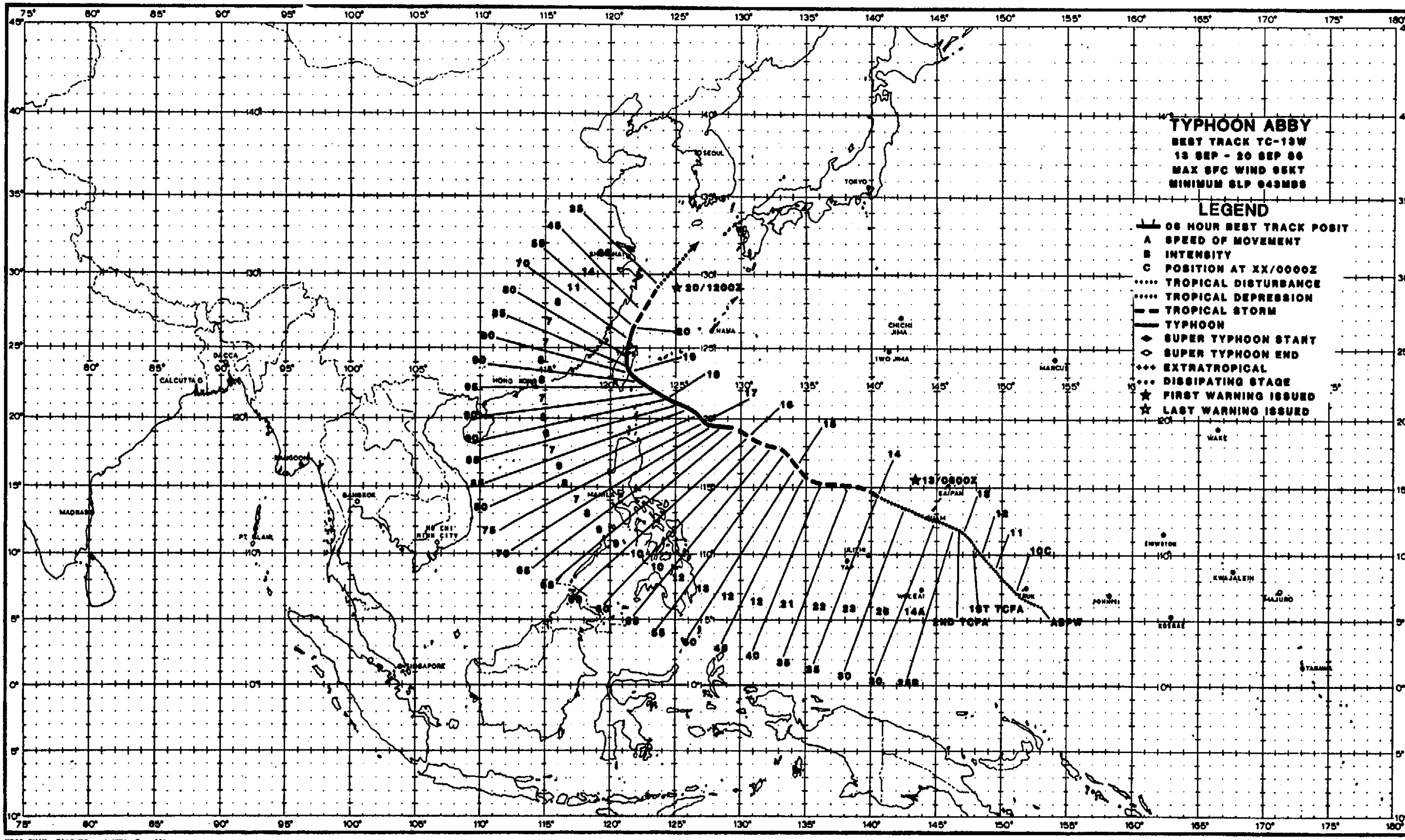
Figure 3-12-5. The 271200Z August 1986 Surface Synoptic Chart. Note the 30 kt (15 m/sec) and 40 kt (21 m/sec) ship reports associated with Wayne.

for the second time. The 271200Z surface analysis (Figure 3-12-5) showed a MSLP of 998 mb, 30 kt (15 m/sec) ship reports, and 40 kt (21 m/sec) ship reports - indications that Wayne had regenerated. These synoptic data, coupled with supporting satellite reconnaissance inputs, prompted JTWC to begin issuing warnings again on Tropical Storm Wayne at 280000Z. Wayne headed northeastward through the Luzon Strait for the second time.

By 31 August, low- to mid-level ridging built back across the East China Sea in Vera's (11W) wake. Wayne's movement toward the northeast slowed and changed toward the southwest - back through the Luzon Strait on the 2nd of September for the third time! After 301200Z, and until 051800Z, Wayne maintained typhoon intensity (Figure 3-12-6). Once through the strait, the typhoon accelerated westward. As it moved away from Luzon, Wayne reached its peak intensity of 90 kt (46 m/sec) at 040000Z. Wayne then moved south of Hong Kong, north of the island of Hainan and across the northern Gulf of Tonkin before dissipating over land over southern China. JTWC issued its final warning at 060600Z.

As a result of Typhoon Wayne, 52 people were reported killed and 97 people were reported injured in Taiwan. On Luzon, 19 people were reported killed and hundreds of people were reported injured. In Vietnam, dozens of people were reported killed in addition to the hundreds reported injured. In total, tens of thousands of people were left homeless and millions of dollars worth of damages were sustained to crops and property due to torrential rain induced flooding and high winds. In summary, Wayne was an extremely long-lived, complex, difficult to forecast "midget" typhoon that struck Taiwan twice, transited the Luzon Strait three times, caused extensive damage and loss of life, and proved to be one for the record books.

Figure 3-12-6. Wayne at typhoon intensity southeast of Taiwan as seen by the Hualien radar (WMO 46699) at 301200Z August (Photograph courtesy of the Central Weather Bureau, Taipei, Taiwan).


TYPHOON ABBY
BEST TRACK TC-13W
13 SEP - 20 SEP 86
LEGEND
06 HOUR BEST TRACK POSIT
A SPEED OF MOVEMENT
B INTENSITY
C POSITION AT XX/0000Z
TROPICAL DISTURBANCE
TROPICAL DEPRESSION
TROPICAL STORM
TYPHOON
SUPER TYPHOON START
SUPER TYPHOON END
EXTRATROPICAL
DISSIPATING STAGE
FIRST WARNING ISSUED
LAST WARNING ISSUED
13/0600Z
20/1200Z
1ST TCFA
2ND TCFA
ABPW
HONG KONG
MANILA
SAIPAN
GUAM
TOKYO
SEOUL
CHICHI JIMA
IWO JIMA
MARCUS
WAKE
ENIWETOK
KWAJALEIN
MAJURO
KOSRAE
PONAPE
TRUK
WOLEAI
ULITHI
YAP
BANGKOK
HO CHI MINH CITY
SINGAPORE
CALCUTTA
DACCA
MADRAS
PT BLAIR
RANGOON
NAHA
SHANGHAI
TARAWA

Typhoon Abby developed in low latitudes from a broad area of convection, moved northwestward and eventually recurved around the subtropical ridge. While in its formative stage, Abby gave indications that it might develop rapidly, however, it caused little, if any, damage when it passed within 30 nm (56 km) south-southwest of Guam. Later as a typhoon, it inflicted heavy damage and loss of life on the island of Taiwan.

During the end of August and beginning of September, the monsoon trough extended eastward from its normal position along 20 degrees North Latitude between 140 and 180 degrees East Longitude. This displacement, coupled with mean pressures two millibars below normal in the monsoon trough and higher than normal pressures to the south (in the Tasman Sea), resulted in stronger surface near-equatorial westerlies from New Guinea eastward into the Gilbert Islands. This increased low-level westerly flow, along with enhanced convection, raised the potential for tropical cyclone genesis within the monsoon trough. These factors, plus low vertical wind shear (Figure 3-13-1) associated with an area of persistent convection southwest of Truk, prompted mention on the 091930Z Significant Tropical Weather Advisory (ABPW PGTW). For three days this area of cloudiness continued to develop slowly as it drifted toward the northwest. Daylight aircraft reconnaissance on the 10th, 11th and 12th of September found only broad surface troughing, minimum sea-level pressures of 1006 mb and 20 to 25 kt (10 to 13 m/sec) surface winds.

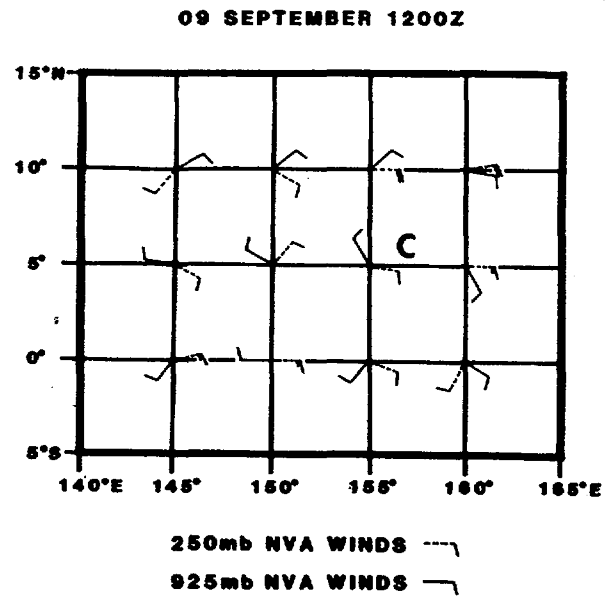


Figure 3-13-1. Differences between the 925 mb and 250 mb NVA winds on 091200Z September define an area of low vertical wind shear favorable for tropical cyclogenesis. Solid lines indicate 925 mb winds; dashed lines indicate 250 mb winds.

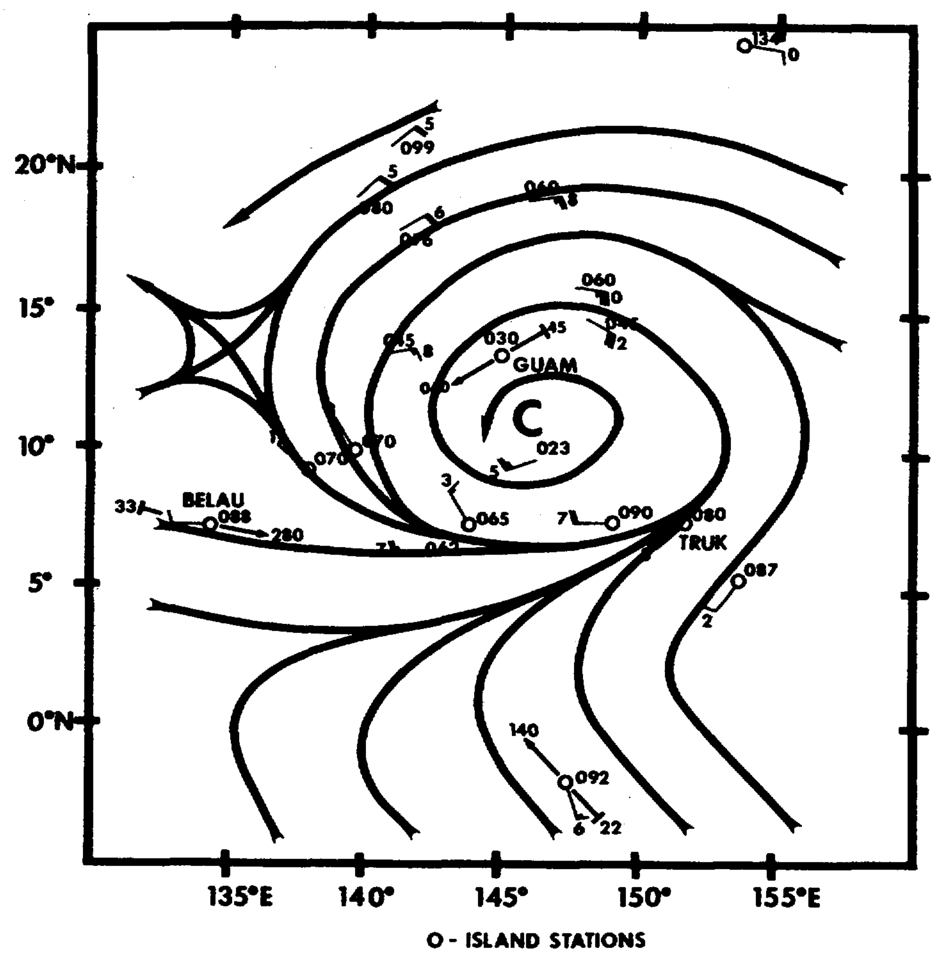


Figure 3-13-2. 130000Z September 1986 surface/gradient-level streamline analysis showing synoptic reports which prompted the first warning on Typhoon Abby.

The 130000Z surface/gradient-level streamline analysis included one 35 kt (18 m/sec) ship report, one 30 kt (15 m/sec) ship report, one 33 kt (17 m/sec) gradient-level wind report and indicated that a minimum sea-level pressure of 1002 mb was associated with the system (Figure 3-13-2). Based on this information, the first warning was issued at 130600Z, which located Tropical Depression 13W 120 nm (222 km) southeast of Guam. During this early period, Abby was a large disturbance, which lacked a persistent central dense overcast (CDO) (Figure 3-13-3). Beginning at 140600Z, however, Abby began to develop its CDO. Twelve to eighteen hours later, when the CDO feature became firmly established, Abby slowed its forward motion and intensified. As a point of interest, the band of maximum flight-level winds was displaced 70 to 120 nm (130 to 222 km) from the 700 mb center on 16 September (Figure 3-13-4).

Abby reached its maximum intensity of 95 kt (49 m/sec) at 181200Z. Twelve hours later, it swept past the east central portion of Taiwan (Figure 3-13-5) with 90 kt (46 m/sec) surface winds and torrential rains. As a result, 13 people were killed; crop and property damage were estimated at 81 million dollars.

Typhoon Abby decreased significantly in intensity following its collision with Taiwan. The upper-level circulation traveled across the island while the low-level circulation moved up the island's east coast. Without the upper-level circulation and supporting convection, the low-level vortex weakened and accelerated toward the north-northeast. At 201200Z, the final warning was issued on Abby as it dissipated over the East China Sea.

In retrospect, as Abby approached Taiwan and recurved there were some data collection problems. Aircraft reconnaissance data to support warnings was limited due to reduced aircraft availability, the proximity of the no-fly line and the rugged island topography. Determining the initial position of Abby was complicated as a result.

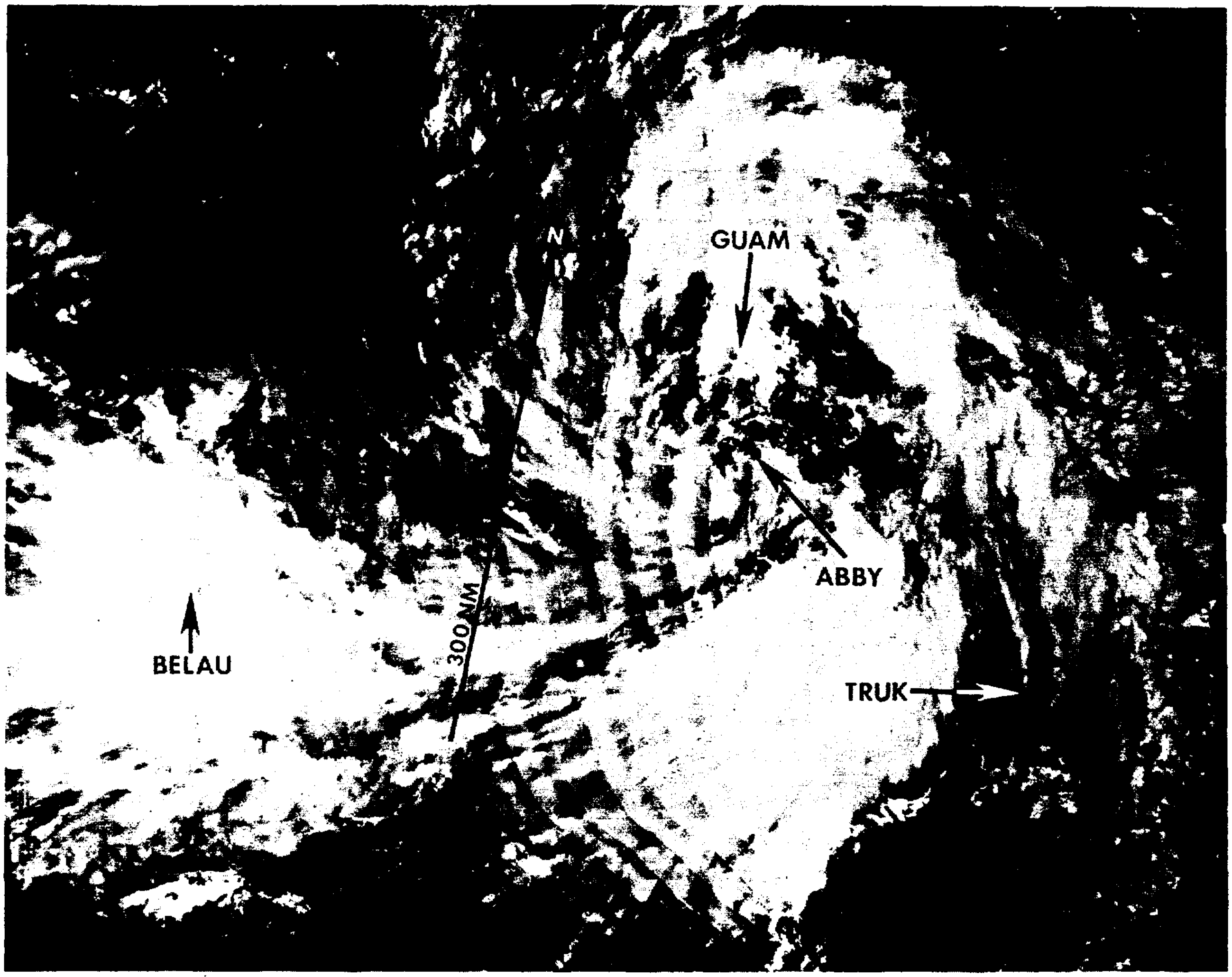


Figure 3-13-3. Tropical Depression 13W without a persistent central dense overcast (130508Z September NOAA visual imagery). The wavy lines in the imagery are due to temporary problems with the tactical sites processing equipment.

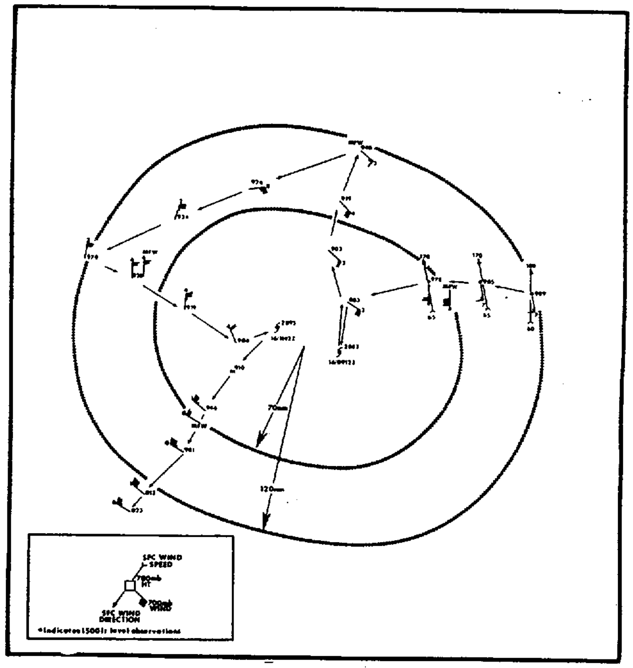


Figure 3-13-4. In-flight 700 mb winds from aircraft reconnaissance on 16 September 1986. Note the stronger winds are displaced outward from the center in a band by approximately 70 to 120 nm (130 to 222 km).

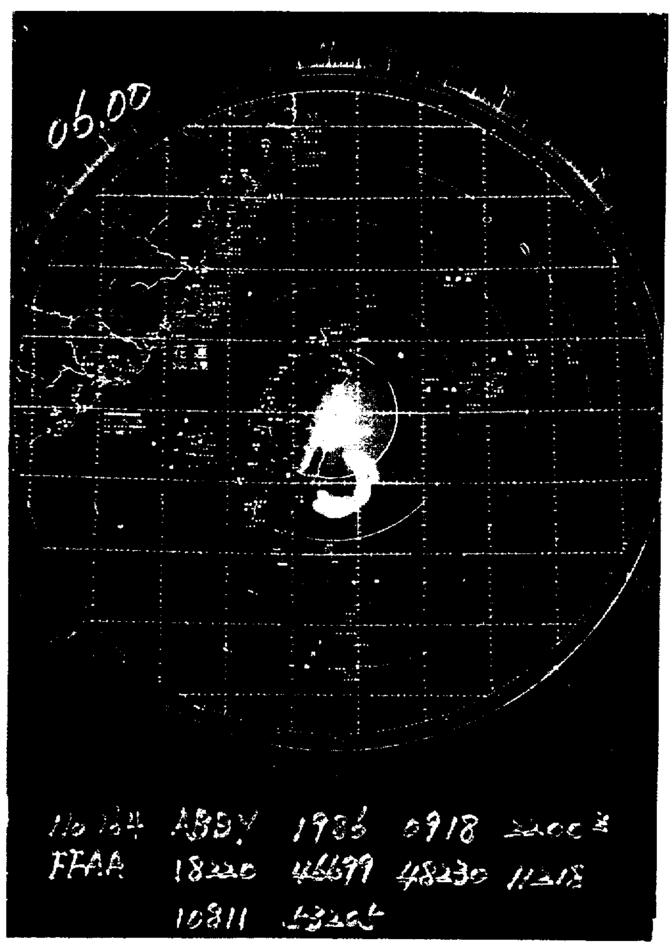
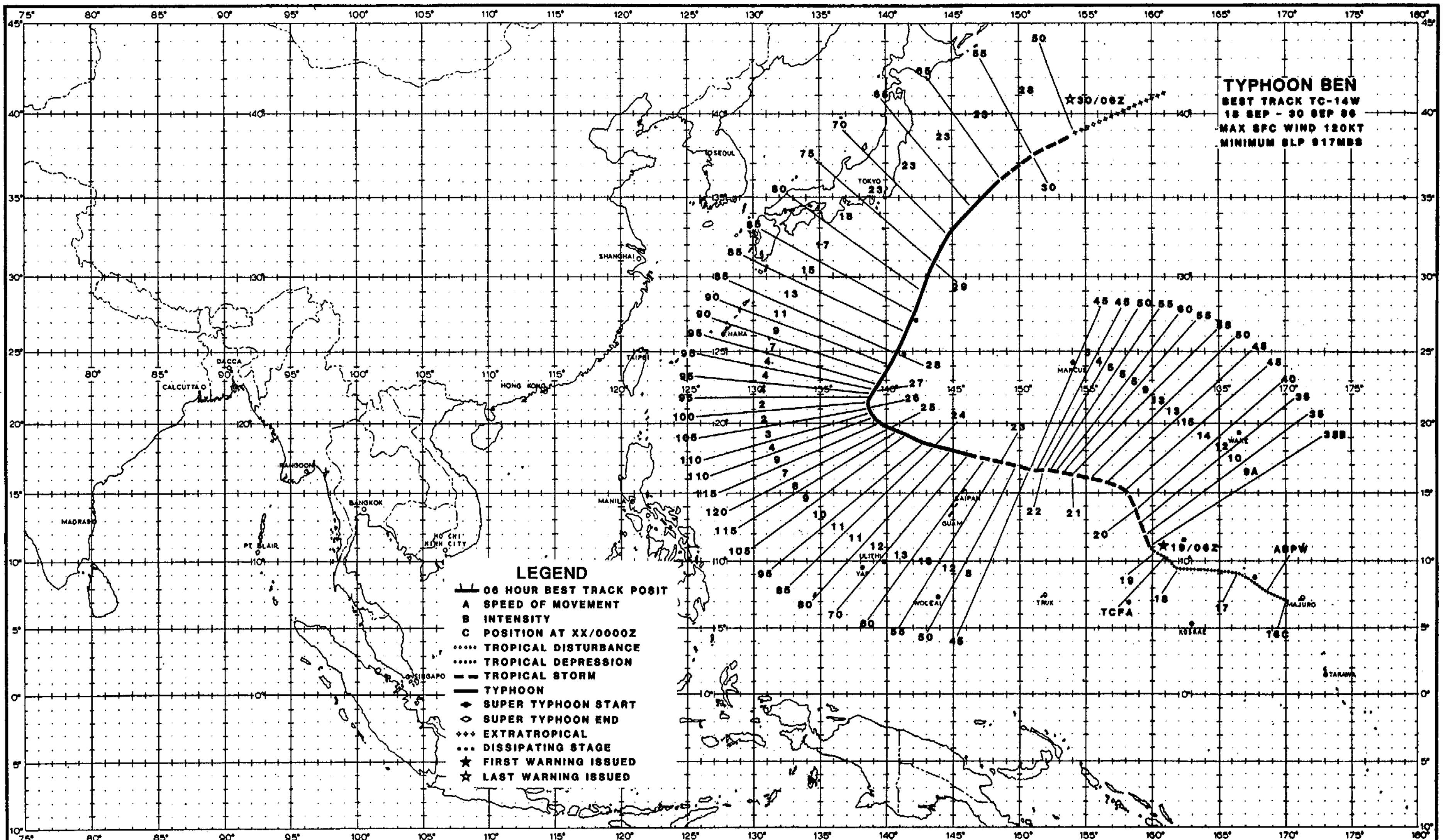


Figure 3-13-5. Radar view of Typhoon Abby as it approaches eastern Taiwan, 182300Z September (Hualien, Taiwan (WMO 46699)).



NOCC GUAM 3142/20 (NEW 5 - 80)

Typhoon Ben was the second of two tropical cyclones that reached warning status in the western North Pacific in September. Ben resulted in the loss at sea of thirteen fishermen from Saipan, who had sought shelter, as it passed by the island of Pagan in the northern Marianas. (The tragedy of the lost fishermen at Pagan was that, although the advanced warning was accurate, the captain apparently decided to leave Saipan for the northern islands anyway.) It was a long-lived typhoon with 46 warnings issued between the 19th and 30th of September.

Typhoon Ben developed from an area of enhanced convection on the 16th of September 165 nm (306 km) southeast of Kwajalein Atoll in the Marshall Islands. It was mentioned for the first time on the Significant Tropical Weather Advisory (ABPW PGTW) later that day. A Tropical Cyclone Forecast Alert was issued two days later, at 181830Z, after satellite imagery (Figures 3-14-1 and 3-14-2) indicated a rapid increase in the amount and organization of convection. The Dvorak intensity estimate was 35 kt (18 m/sec).

The first warning on Ben, as Tropical Depression 14W, was issued on the 19th, valid at 0000Z. Ben's initial warning position, which was based on satellite data, was 180 nm (333 km) north of the island of Pohnpei. Later, aircraft reconnaissance data at 190730Z resulted in a 160 nm (296 km) relocation of Ben to the northeast and upgrade from tropical depression to tropical storm intensity on the second warning.

Ben's initial forecast track was west-northwestward with a gradual intensity increase. The early forecast tracks were in close agreement with dynamical and statistical guidance. This made Ben an immediate threat to the island of Guam. However, Ben did not track as forecast, but instead moved north-northwestward until the 20th at 0600Z; after which it began a west-northwesterly track towards the northern Marianas.

Ben was forecast to reach typhoon intensity between 200600Z and 210600Z September. However, its forward movement slowed and its intensity decreased to 45 kt (23 m/sec) of maximum sustained surface winds. This decrease was due to increased vertical shear from the north-northeast. At 212124Z, the deep central convection became displaced southwestward and exposed the low-level circulation (Figure 3-14-3).

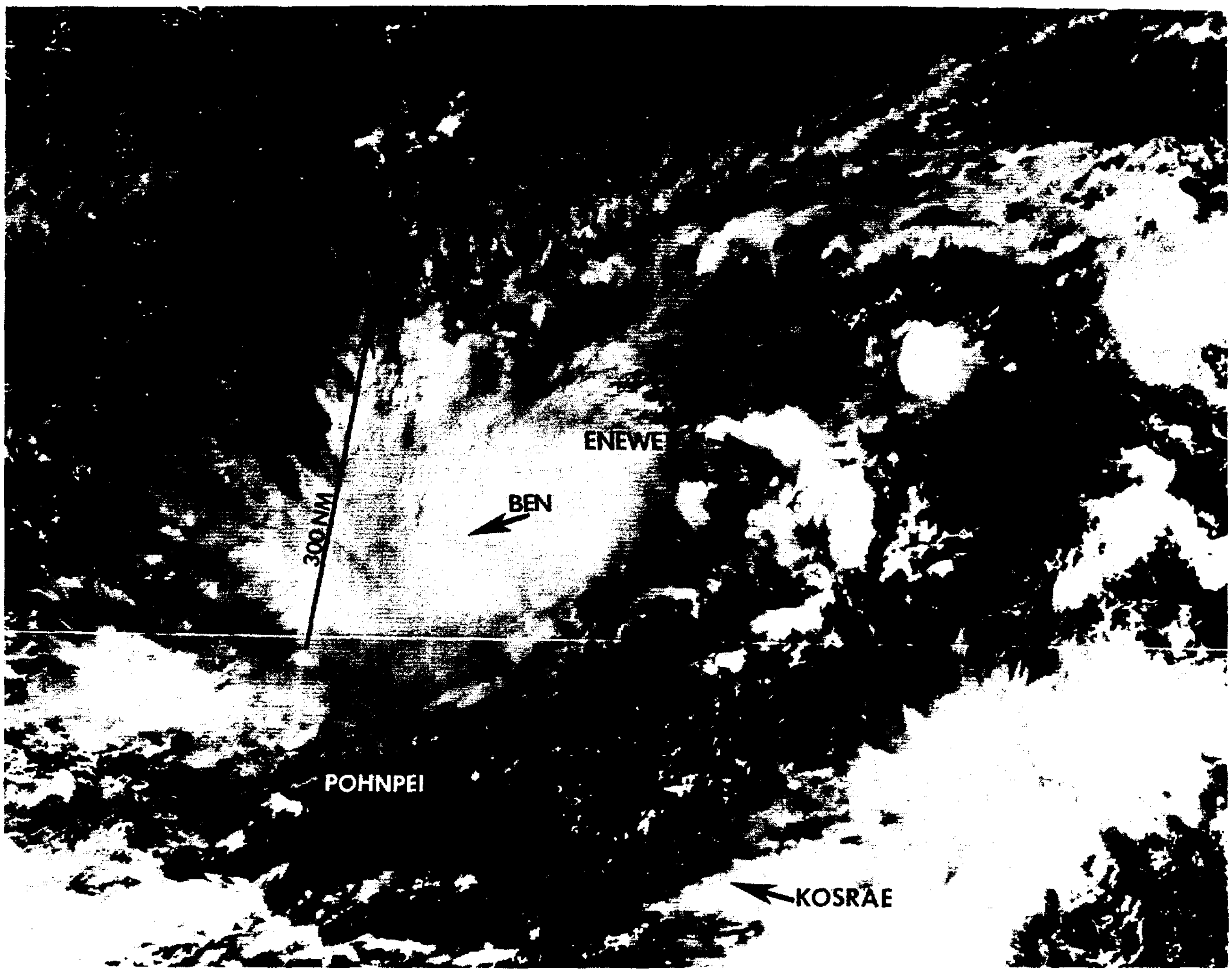


Figure 3-14-1. Typhoon Ben as a tropical disturbance (182255Z September DMSP visual imagery).

The central dense overcast had reestablished itself by 221600Z. By the 23th, Ben had increased its forward speed toward the west-northwest and intensified. It reached typhoon intensity at 230900Z just five hours before passing 20 nm (37 km) south of Pagan Island (located 270 nm (500 km) north of Guam). Ben continued to intensify through 250000Z, when its maximum sustained winds peaked at 120 kt (62 m/sec). At that time, its minimum sea-level pressure (MSLP) was 917 mb. Ben had a circular eye 40 nm (74 km) in diameter (Figure 3-14-4).

Forecasts through 250000Z indicated a gradual turn from northwestward to northward, however, Ben slowed to 2 kt (4 km/hr) by early on the 26th and drifted slowly northward into a region of increasing upper-level southwesterlies. Once Ben moved to the north of the mid-level subtropical ridge axis, the forecasts, based on a combination of dynamic and statistical aids for the track, were more accurate. Acceleration, after recurvature, was handled well by the empirical Typhoon Acceleration Prediction Technique (Weir, 1980).

As interaction with the southwesterlies aloft increased, Ben's central cloudiness became elongated north-northeast/south-southwest. At 261451Z, aircraft reconnaissance indicated that the eyewall had become ragged and open to the southwest. The MSLP had risen to 946 mb.

By 280000Z, Ben's forward speed had increased to 13 kt (24 km/hr) and its intensity had gradually decreased to 85 kt (44 m/sec). The central convection sheared away and was displaced to the northeast as the intensity decreased to 50 kt (26 m/sec). By the time the final warning was issued at 300600Z, transition to an extratropical system was complete.

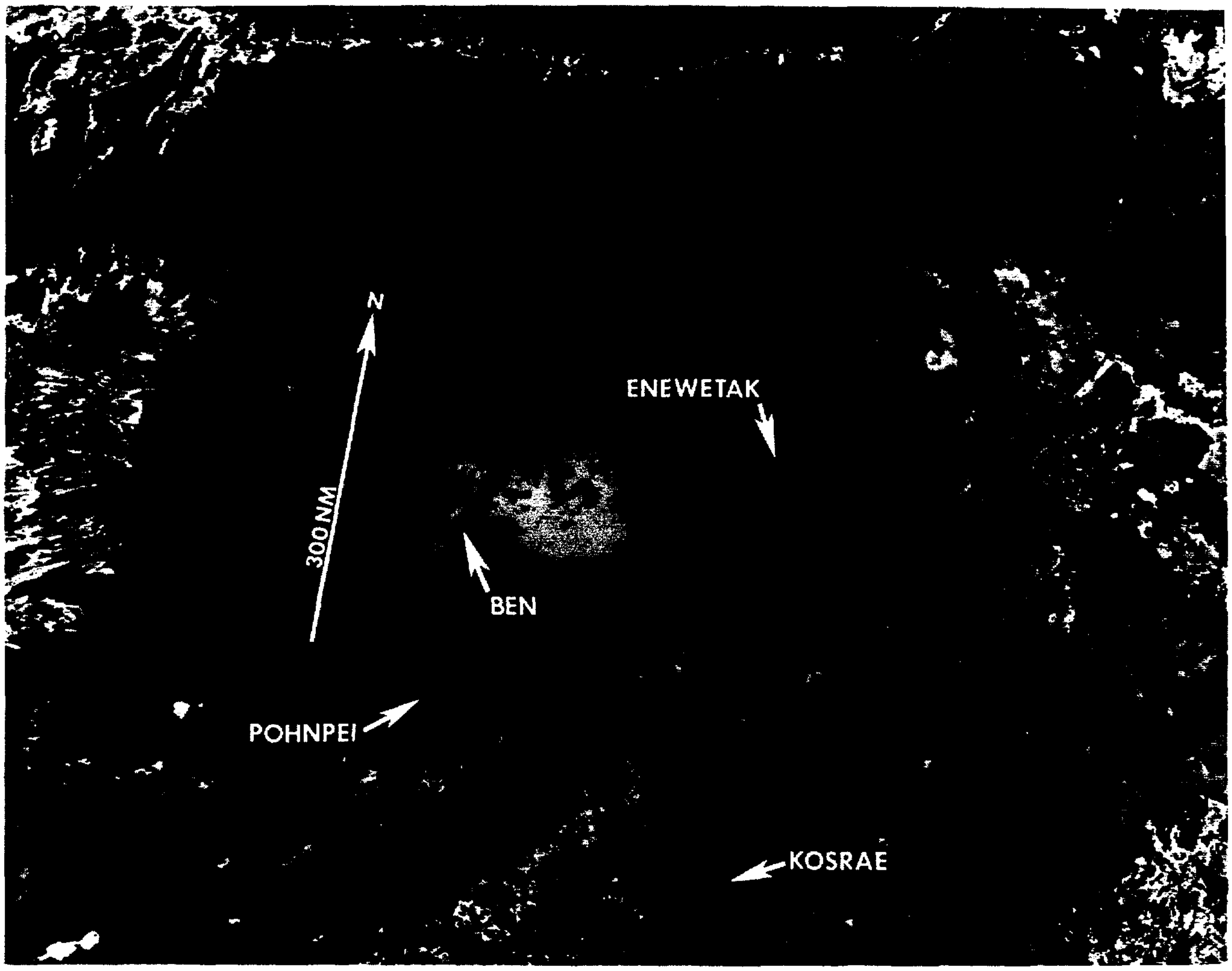


Figure 3-14-2. Enhanced infrared imagery of Ben assisted in locating the areas of vigorous convection (182255Z September DMSP infrared imagery).

Figure 3-14-3. Strong northerly upper-level flow displaces convection to the south of Ben's low-level circulation (212124Z September NOAA visual imagery).

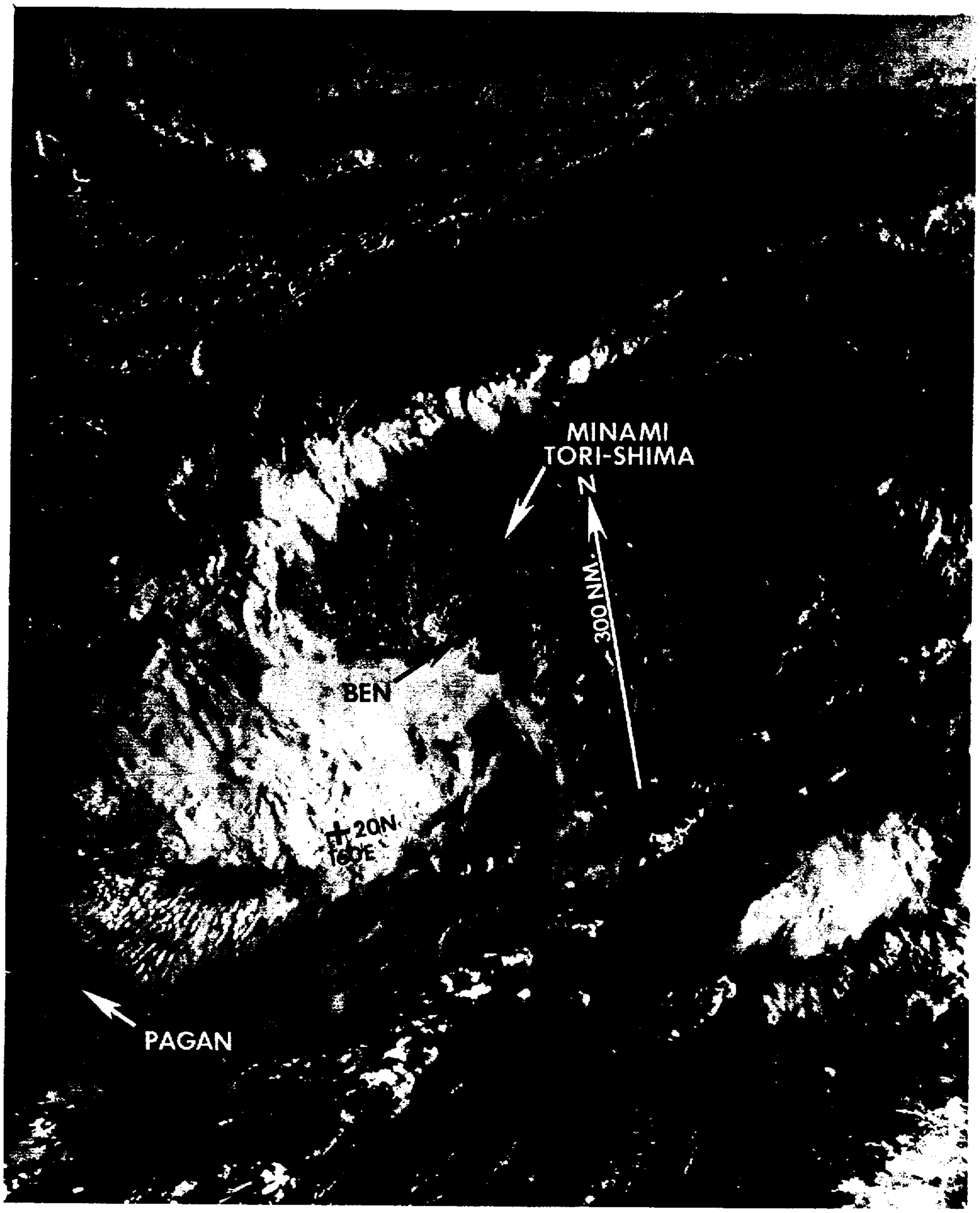
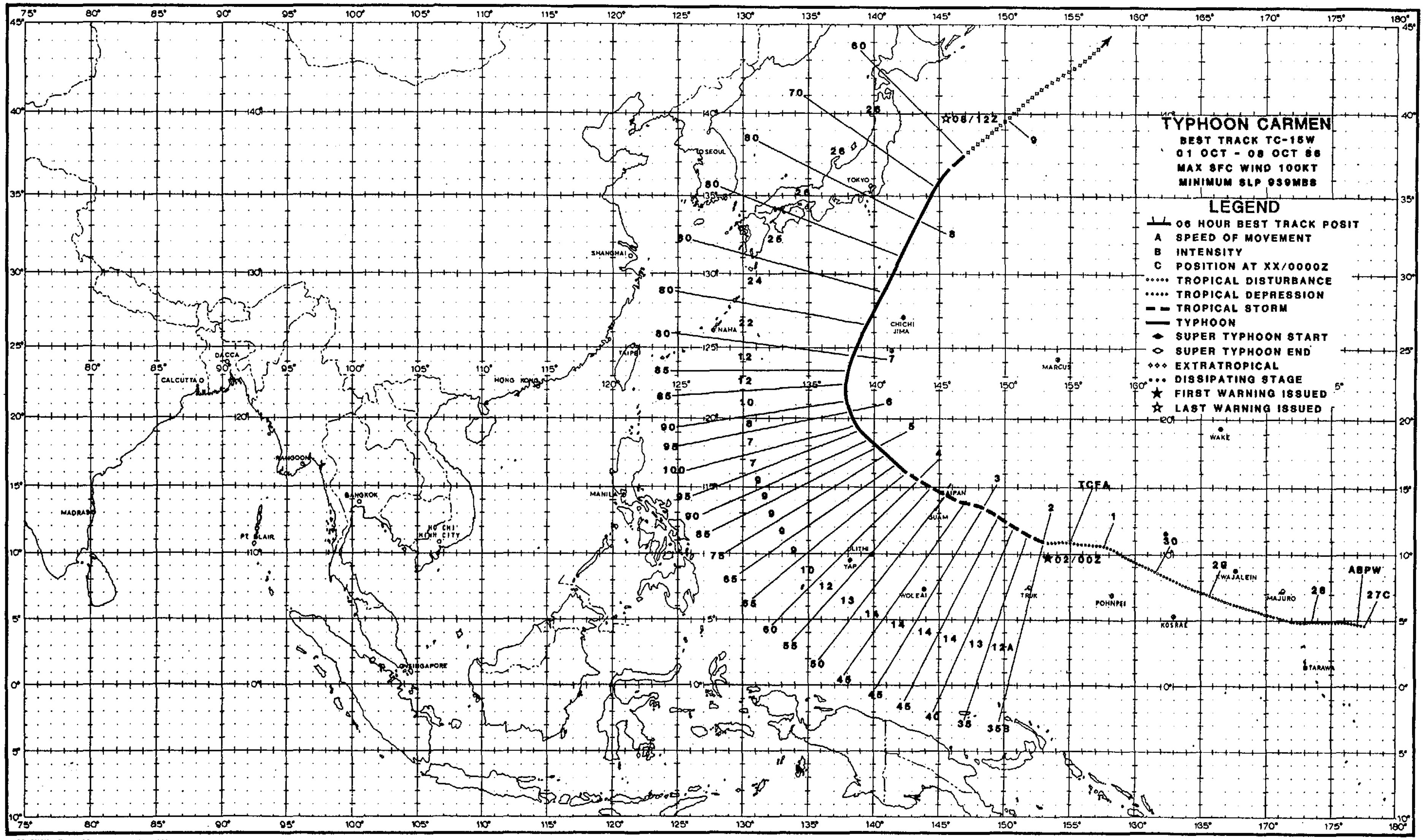


Figure 3-14-4. Two and one-half hours before Ben reached its peak intensity of 120 kt (62 m/sec). A circular eye 40 nm (74 km) in diameter is visible (242134Z September DMSP visual imagery).



NOCC GUAM 3142/20 (NEW 5 - 80)

Typhoon Carmen (15W) was the first of five significant tropical cyclones that occurred in October. Carmen followed a recurvature track that took the system between Guam and Saipan. Carmen was slow developing, but deepened rapidly prior to recurvature. The point of recurvature was 935 nm (1730 km) east of Taiwan. JTWC's forecast statistics were excellent.

Carmen spawned in an area of convergent flow associated with the near-equatorial trough east of the dateline. On 270600Z September, the disturbed area that became Carmen was first mentioned on the Significant Tropical Weather Advisory (ABPW PGTW) 350 nm (648 km) east of Majuro Atoll. The poorly organized convection was enhanced by divergent flow aloft. At 270000Z, when the surface vorticity center was first noted on satellite imagery, the minimum sea-level pressure (MSLP) was estimated to be 1009 mb, and the maximum surface winds 10 to 15 kt (5 to 8 m/sec). The tropical disturbance's organization remained poor for the next four days.

A Tropical Cyclone Formation Alert was issued on 011230Z October based on a flare-up of cloudiness detected on the satellite imagery. Because of the system's rapid development and location 330 nm (611 km) east-southeast of Guam, it presented an immediate threat to the island. The first warning for Tropical Depression 15W followed 11-hours later when satellite imagery showed continued growth. Later, aircraft reconnaissance at 020326Z fixed a low-level circulation center 480 nm (889 km) east of Guam, which was a significant displacement from the earlier satellite derived position. These data, which included a MSLP of 1001 mb, maximum 1500 ft (457 meters) winds of 45 kt (23 m/sec), and maximum surface winds of 40 kt (21 m/sec), led JTWC to relocate and upgrade Carmen to tropical storm intensity. Initially Carmen was forecast to pass south of Guam. It soon became evident that a track between the islands of Guam and Saipan was preferred.

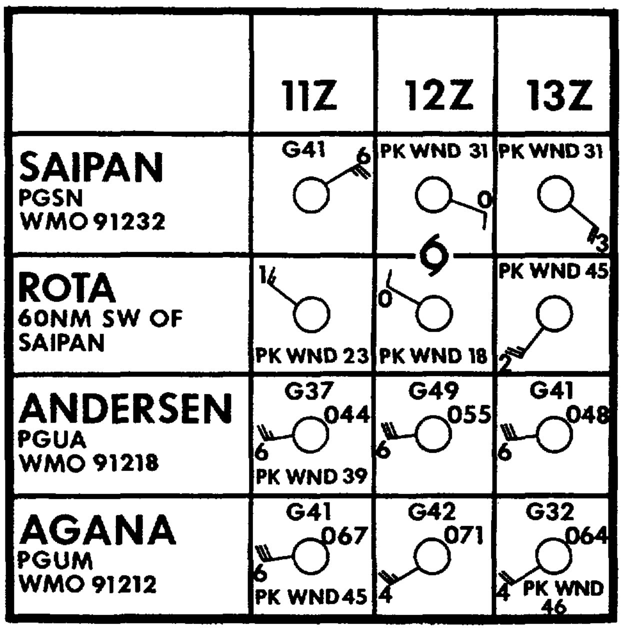


Figure 3-15-1. Synoptic data showing Carmen's passage between Saipan (WMO 91232) and the island of Rota, which is 60 nm (111 km) southwest of Saipan.

Figure 3-15-2. Winds and heavy rainshowers affect travelers on Guam on 3 October (Photo courtesy of Guam Publications, Inc.).

Carmen intensified at a slower rate than normal. This slow intensification was advantageous for the Mariana Islands. The maximum intensity at the time of passage through the Marianas was only 55 kt (28 m/sec) instead of an expected 77 kt (40 m/sec). The synoptic data (see Figure 3-15-1) reflects Carmen's presence between the islands of Rota, which is 60 nm (111 km) southwest of Saipan, and Saipan (WMO 91232) at 031200Z. Automated weather reporting stations provided the timely observations from Rota and Saipan. Maximum wind reports from Saipan were 31 kt (16 m/sec) with gusts to 41 kt (21 m/sec) at 031200Z; for Rota, 35 kt (18 m/sec) with gusts to 53 kt (27 m/sec) at 031500Z; and for Guam (Figure 3-15-2), 30 kt (15 m/sec) with gusts to 40 kt (21 m/sec) at 031155Z. Carmen did bring heavy rain, 10 to 11 inches (254 to 279 mm) for Guam, and flooding to the southern Mariana Islands, but caused little structural damage and no loss of life.

Aircraft reconnaissance at 032350Z, which reported a MSLP of 993 mb and estimated the maximum surface wind to be 65 to 70 kt (33 to 36 m/sec), led JTWC to upgrade Carmen from tropical storm to typhoon. Aircraft reconnaissance at 042355Z reported a drop in MSLP of 26 mb to 967 mb and at 051510Z reported another drop of 28 mb to a MSLP of 939 mb. This was a total decrease of 54 mb or an average of 1.4 mb/hr for 39-hours (see Figures 3-15-3, 3-15-4 and 3-15-5).

The forecasts for the recurvature of Carmen were excellent. The 72-hour forecast errors covering eight warnings (the third warning through the tenth) were less than 80 nm (148 km). One of the pieces of data that helped was a synoptic track requested and flown on 03 October from 0000Z to 1500Z. This synoptic track (see Figure 3-15-6) revealed a weakness at 500 mb in the subtropical ridge 480 nm (889 km) northwest of Guam.

Typhoon Carmen reached its maximum intensity of 100 kt (51 m/sec) with gusts to 125 kt (64 m/sec) at 051800Z. Afterward, cooler, drier air associated with a mid-latitude trough east of Japan, was entrained into the system. The aircraft mission at 052306Z reported that the eyewall had become ragged in the south through northwest segment. Satellite imagery at 061200Z confirmed Carmen was being sheared from the west by strong upper-level southwesterly flow, which caused the tropical cyclone to become elongated southwest to northeast. By that time,

Figure 3-15-3. Typhoon Carmen before rapid deepening and just after it passed Guam (040444Z October NOAA visual imagery).

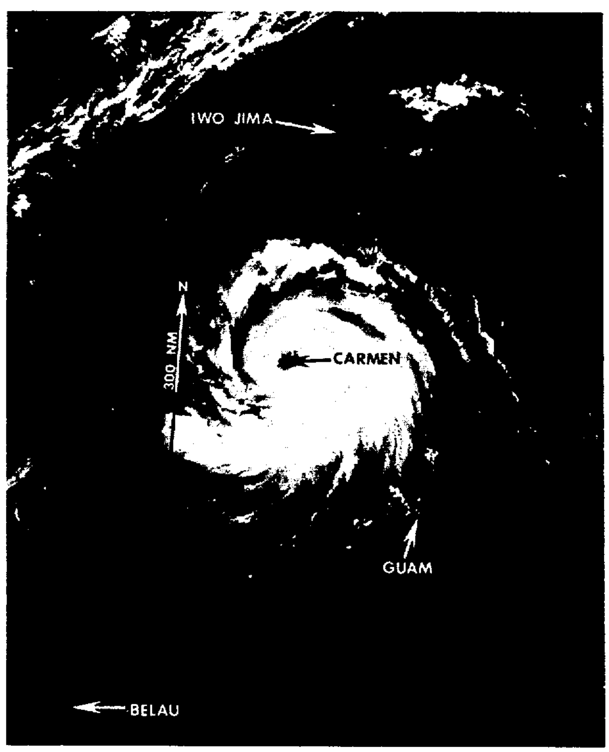


Figure 3-15-4. A mature Typhoon Carmen 19-hours after Figure 3-15-3 and rapid deepening (050013Z October DMSP visual imagery).

Carmen had already passed its point of recurvature. At 070005Z, the aircraft reconnaissance reported moderate to severe turbulence in the northwest quadrant of the system and indicated the eye was no longer present. These were indicators of extratropical transition.

Subsequently, Typhoon Carmen accelerated in forward speed to about 25 kt (13 m/sec), while maintaining an intensity of 80 kt (41 m/sec). After recurvature on October 7th, the MSLP steadily decreased and the winds remained nearly constant. At 071600Z, satellite imagery indicated Carmen had acquired subtropical characteristics and the maximum winds were 65 kt (34 m/sec). A wind maximum on the eastern portion of the trough caused Carmen to accelerate toward the northeast faster than forecast.

JTWC continued warning on Carmen until 081200Z when the system completed extratropical transition. At that time, extratropical Carmen had 60 kt (31 m/sec) maximum winds with gusts to 75 kt (39 m/sec) and was well north of the tropics.

Figure 3-15-5. Inside Typhoon Carmen's eye. This scene is from the aircraft reconnaissance mission (AF966 0715 CARMEN) at 042355Z. Compare the low cloud spiral in this figure with the remotely sensed eye in Figure 3-15-4 (Photo courtesy of Captain Susan K. Watters, USAF).

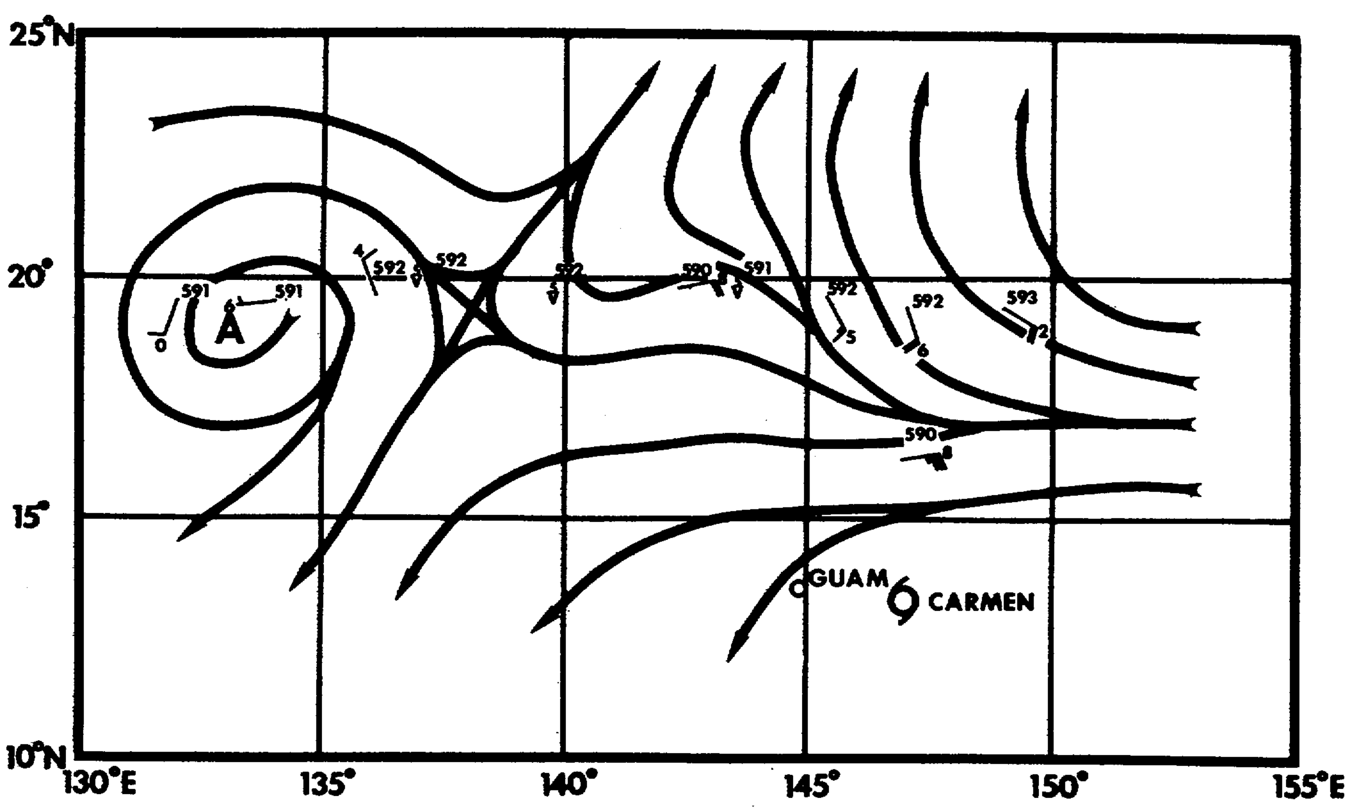
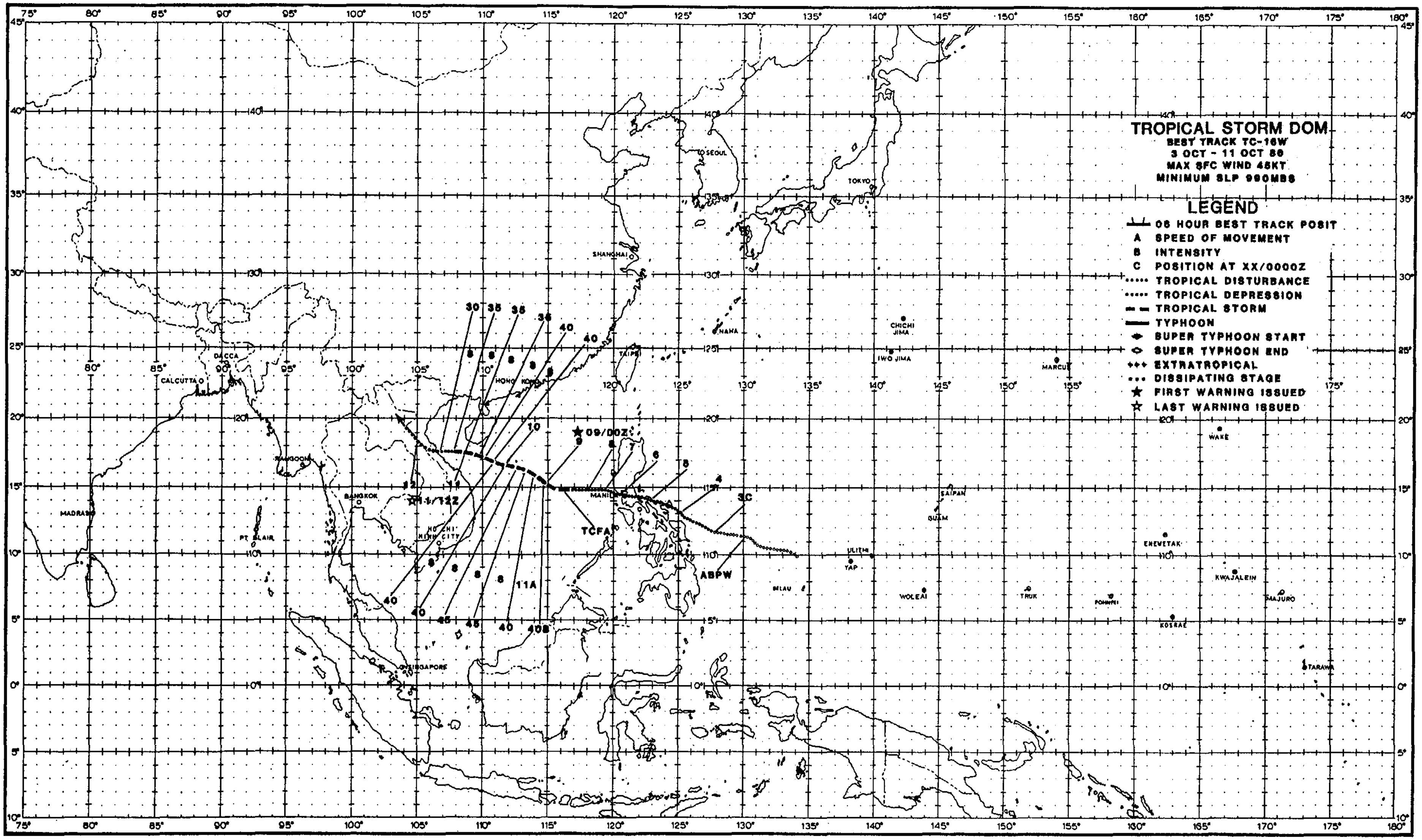
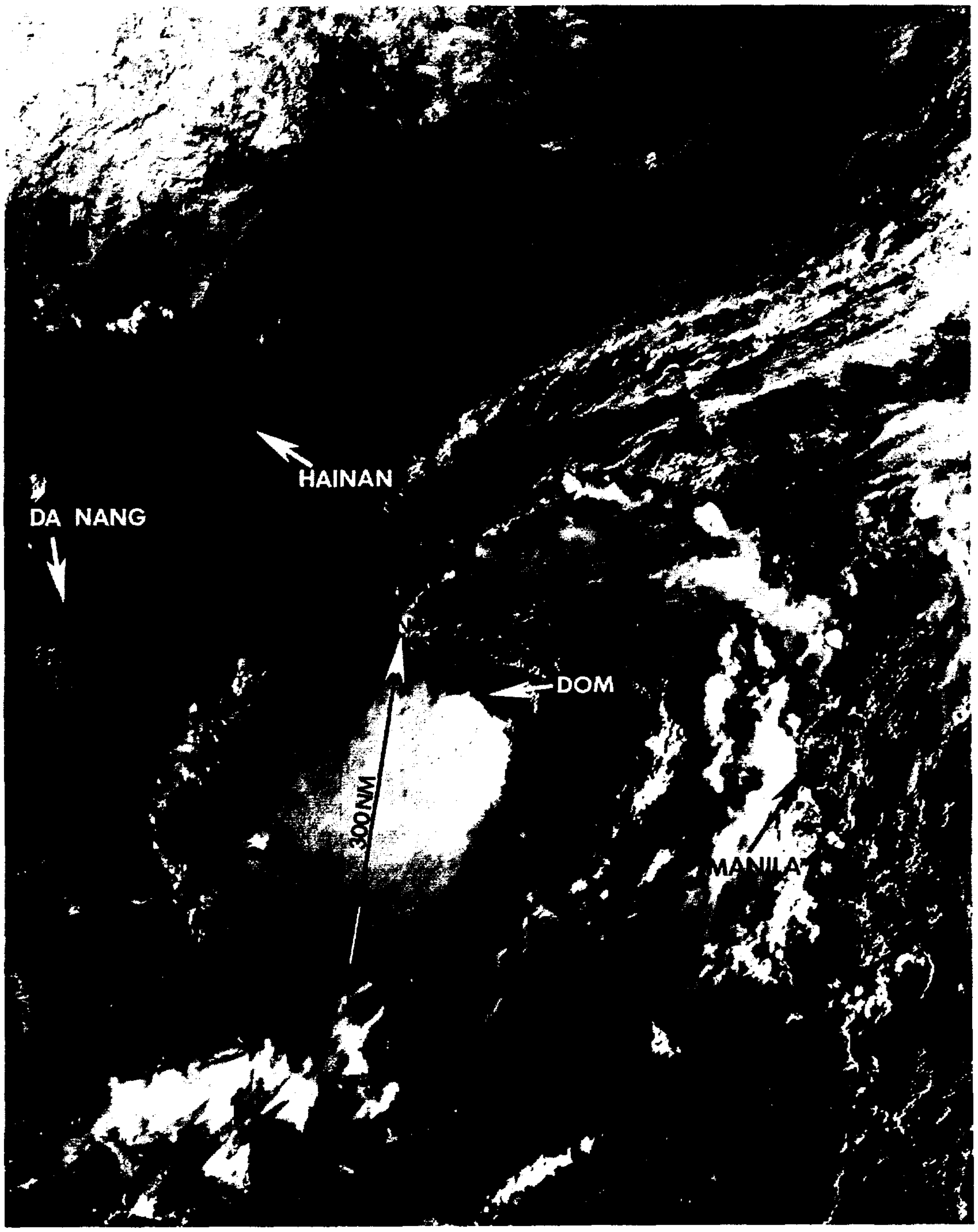


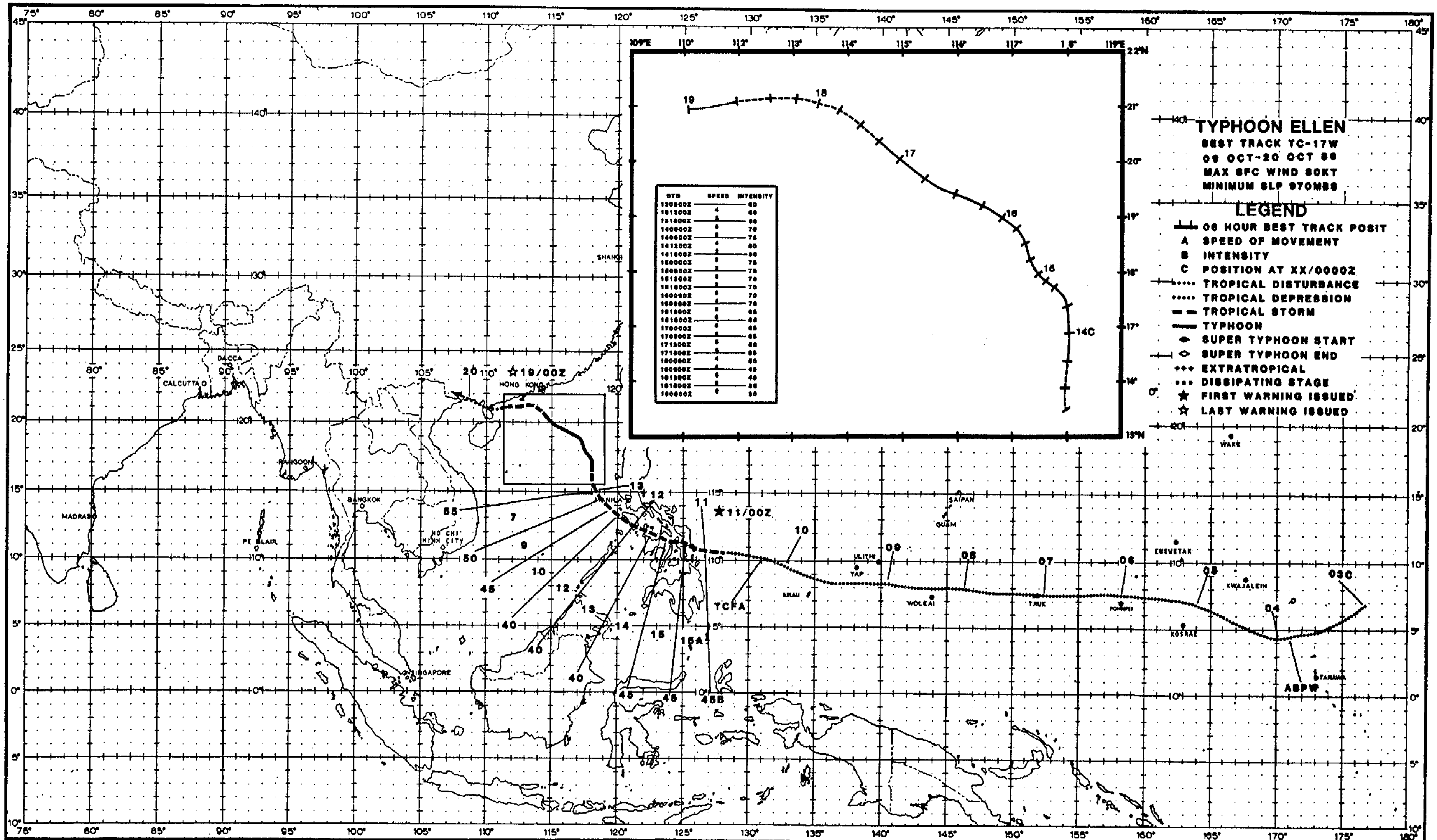
Figure 3-15-6. The synoptic track from 030000Z to 031500Z October 1986 identifies a break in the subtropical ridge.



NOCC GUAM 3142/20 (NEW 5-80)

Figure 3-16-1. Tropical Storm Dom slowly developed from a tropical disturbance 340 nm (630 km) east of the island of Samar in the Republic of the Philippines. It was first detected on satellite imagery on the 2nd of October and placed on the Significant Tropical Weather Advisory (ABPW PGTW) as a suspect area the same day. Dom struggled along for the next six days as it moved west-northwestward across southern Luzon producing heavy rains and flooding. The flood damage prompted the Philippine Meteorological Agency to begin warning on the system prior to JTWC. JTWC issued a Tropical Cyclone Formation Alert at 081800Z when Dom displayed increased organization and convection after entering the South China Sea. Surface winds at that time were estimated at 15 to 25 kt (7 to 12 m/sec). Dom was upgraded to tropical storm intensity on the first warning at 090300Z. The warning was based on aircraft reconnaissance reports of 50 kt (26 m/sec) estimated maximum surface winds and a minimum sea-level pressure of 1002 mb. A well-established ridge located north of Dom provided strong mid- to upper-level northeasterly flow caused Dom's convection to be sheared to the west-southwest of the low-level circulation center. Later, this shear, when combined with the increasing interaction with the rugged terrain of central Vietnam, caused Dom to weaken and dissipate. The last warning on Dom was issued by JTWC for 111200Z. The satellite picture shows Dom just prior to the issuance of the first warning (090215Z October DMSP visual imagery).





NOCC GUAM 3142/20 (NEW 5-80)

Typhoon Ellen was the third cyclone of five that developed in the month of October. It followed close on the heels of Typhoon Carmen (15W) and Tropical Storm Dom (16W). Ellen proved to be a difficult system to forecast, particularly when it encountered weak steering in the South China Sea. The system traveled over 4000 nm (7408 km) from its inception on the 3rd of October 250 nm (463 km) east of the Majuro Atoll in the Marshall Islands to dissipation sixteen days later along the border of southern China and Vietnam.

As Ellen moved westward through the Marshalls, the Significant Tropical Weather Advisory (ABPW PGTW) was reissued late on the 3rd of October, at 1800Z. The disturbance in the monsoon trough had shown signs of improved convective organization on the satellite imagery.

Ellen finally developed into a tropical depression as it passed 120 nm (222 km) south of the island of Ulithi in the Caroline Islands on 9 October. Twenty-four hours later, JTWC issued a Tropical Cyclone Formation Alert when the disturbance again showed an increase in organization. The initial aircraft reconnaissance investigative mission found only a weak circulation in a broad low-pressure trough and estimated surface winds of 10 to 20 kt (5 to 10 m/sec).

By the following morning, Ellen had changed significantly. The second aircraft reconnaissance mission at 110122Z reported a minimum sea-level pressure of 992 mb with estimated surface winds of 45 kt (23 m/sec). JTWC immediately issued its first warning on Tropical Storm Ellen, valid at 110000Z (see Figure 3-17-1).

Shortly after its development into a tropical storm, Ellen moved through the the central Philippine Islands. Only a modest weakening to 40 kt (21 m/sec) resulted during the 24-hours it took to make the passage.

Upon entering the South China Sea on the morning of the 12th, Ellen turned northward into a region of weak steering current and slowed in forward speed. At that point, most of the statistical and dynamic forecast guidance predicted the tropical cyclone

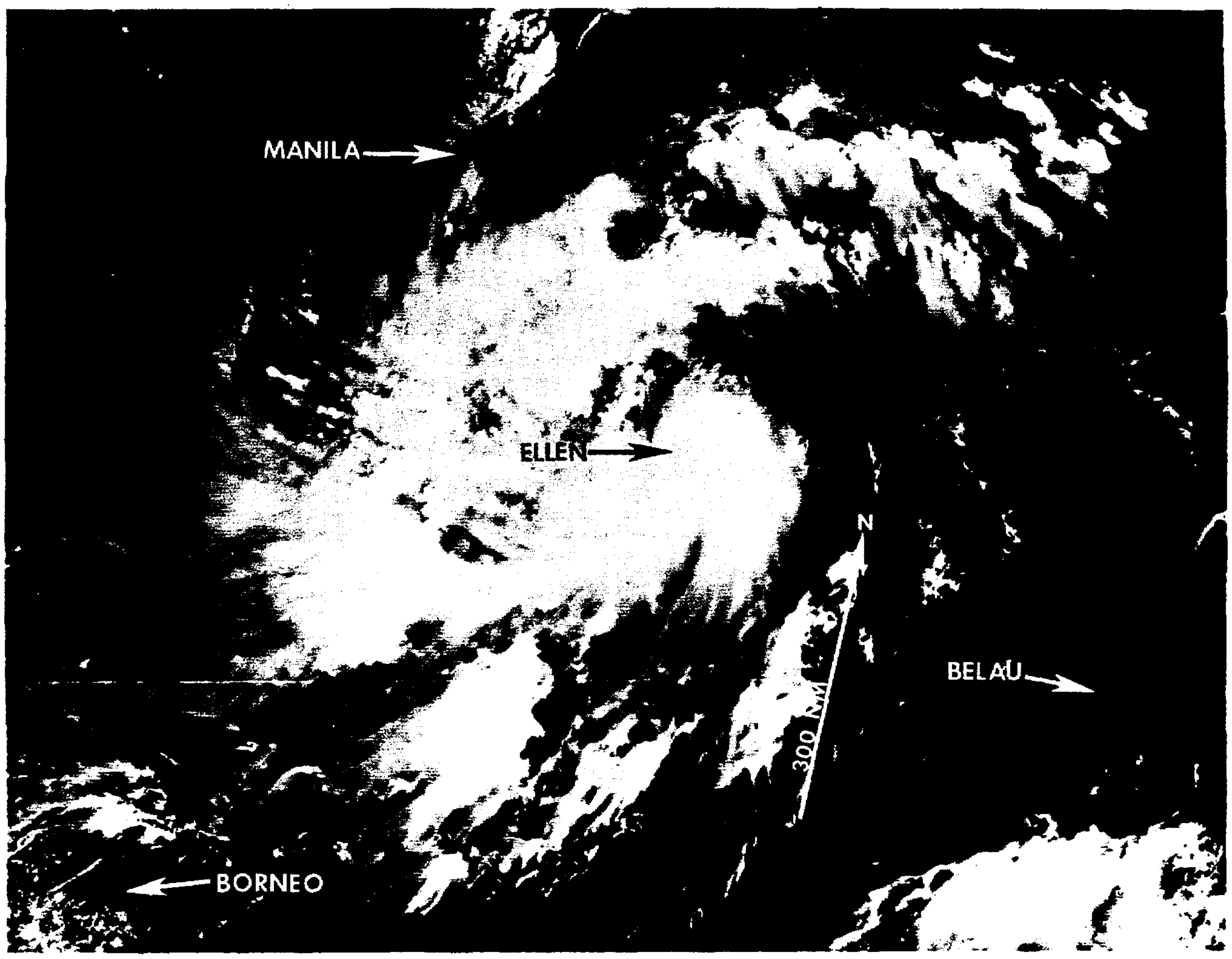


Figure 3-17-1. Tropical Storm Ellen at the time of the second aircraft reconnaissance mission that found 45 kt (23 m/sec) surface winds and a minimum sea-level pressure of 992 mb (110134Z October DMSP visual imagery).

would recurve. This was the forecast philosophy that was followed. Later the One-way Interactive Tropical Cyclone Model (OTCM) changed to a more northwesterly, and eventually, westerly track. JTWC stayed with the recurvature forecast until the 16th when the Typhoon made a definite turn toward the west. Aircraft reconnaissance data provided this critical information. The three hourly movement between the intermediate and on-time vortex fix positions confirmed that Ellen was headed northwest and not northeast. In retrospect, the low-level surge from the northeast across the Yellow Sea, Taiwan, and later, the south coast of China pressured Ellen northwestward.

After reaching a peak intensity of 80 kt (41 m/sec) on the 14th (Figure 3-17-2), the vertical shear from the westerlies remained too weak to shear away the central convection and Ellen maintained tropical storm intensity almost until landfall northeast of the island of Hainan. Figure 3-11-3 provides a radar view of the rainbands as the system passed south of Hong Kong on the 18th. There were no reports received of heavy damage or loss of life attributed to Ellen.

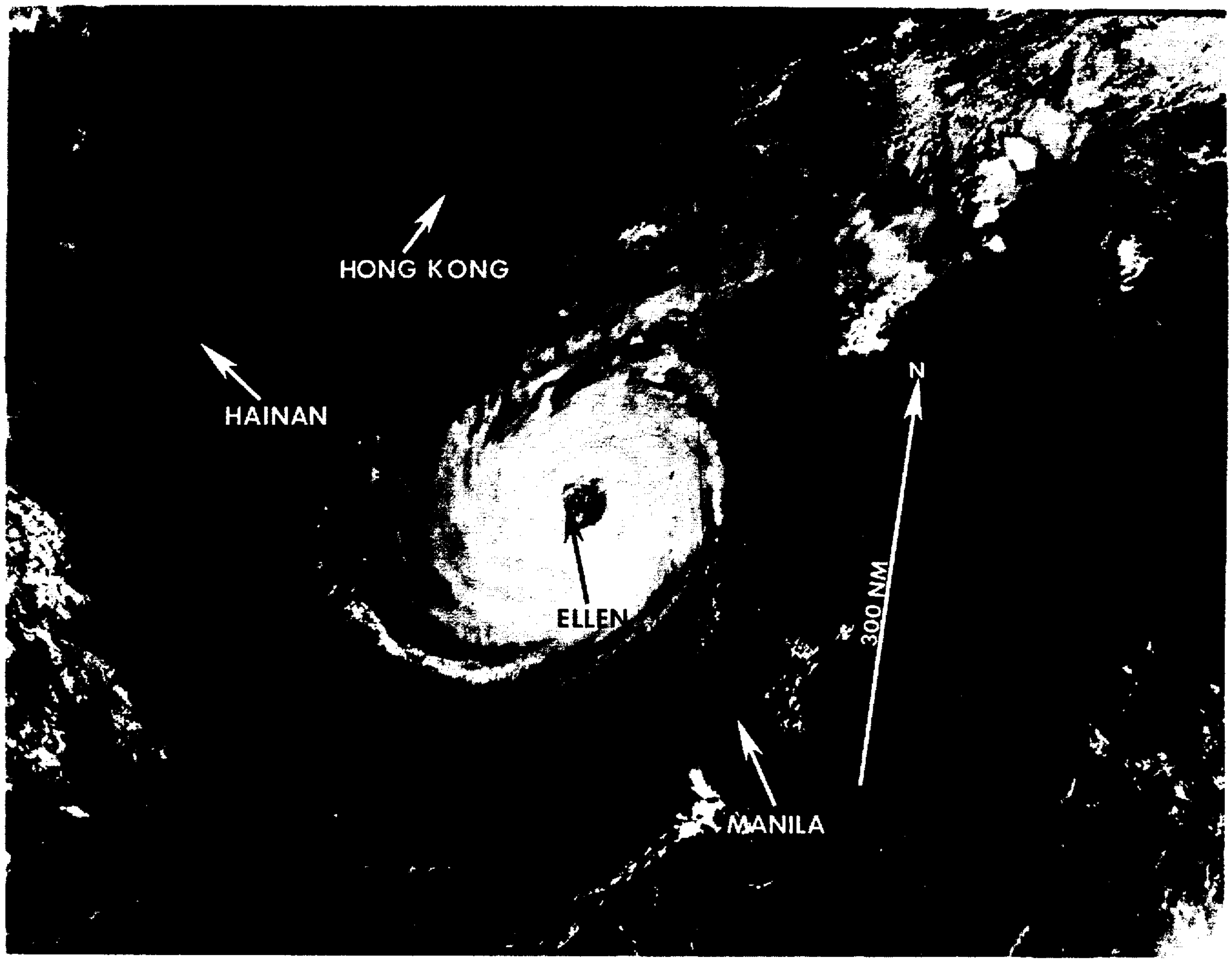
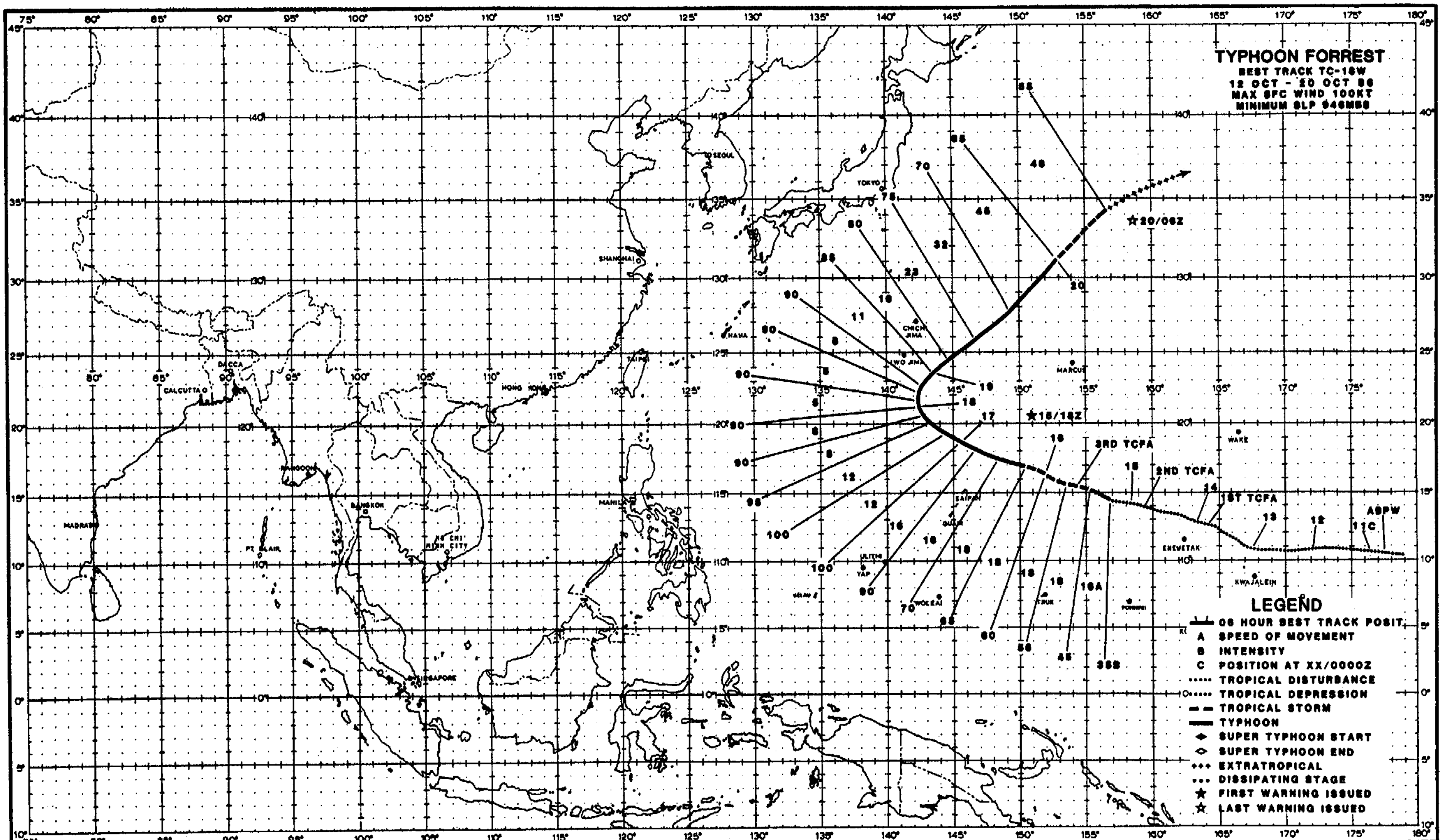


Figure 3-17-2. Weak vertical wind shear over the South China Sea enabled Ellen to intensify into a typhoon. Its large eye is visible to the west of the island of Luzon (150153Z October DMSP visual imagery).

Figure 3-17-3. A digital radar picture of Tropical Storm Ellen as it passed south of Hong Kong on the 18th of October at 0640Z (Picture provided courtesy of the Hong Kong Royal Observatory).



NOCC GUAM 3142/20 (NEW 5 - 80)

Typhoon Forrest was the second tropical cyclone to begin east of the dateline and move westward into the western North Pacific. Forrest was a classic recurver and a small, compact system. The track and intensities were well forecast with the exception of the intensities being a little low through the first half of Forrest's life. An interesting point to note about this system is that the upper-level vortex appeared to develop first and then built downward to the surface. Post-analysis of synoptic and aircraft reconnaissance data indicates the stronger upper- and mid-level winds did not begin to reach the surface until after the 14th of October.

On 9 October, personnel at Detachment 1, 1st Weather Wing, Satellite Operations first detected Forrest on satellite imagery as an area of poorly organized convection in the trade wind trough 600 nm (1111 km) east of the Marshall Islands. Over the next 18-hours the convection began to slowly increase in organization. Once across the dateline, it was first discussed on the Significant Tropical Weather Advisory (ABPW PGTW) at 100600Z. At that stage, the amount of convection began to decrease, but a small cyclonic vorticity center remained. Over the next 48-hours, Forrest remained in a region where the upper-level environment was unfavorable for development. As a result, it remained poorly organized and continued moving west-northwestward. Sparse synoptic data indicated the minimum sea-level pressure (MSLP) was approximately 1008 mb and the maximum sustained surface winds were 10 to 20 kt (5 to 10 m/sec).

The orientation of low-level clouds on the visual satellite imagery at 120000Z revealed a broad circulation center in the western quadrant of deep convection located 320 nm (593 km) east of the Bikini Atoll in the Marshall Island Group. The intensity was estimated to be 25 kt (13 m/sec). Later, at 121800Z, Forrest demonstrated continued growth. This prompted reissuance of the ABPW PGTW at 122000Z to upgrade Forrest's potential for development to fair. This trend towards increased organization (Figure 3-18-1) continued and resulted in a Tropical Cyclone Formation Alert (TCFA) at 132000Z. The first aircraft reconnaissance investigative mission flown into the disturbance on the 14th of October found multiple low-level circulation centers, a MSLP of 1008 mb, maximum winds of 10 to 25 kt (5 to 13 m/sec) near the vortices and 30 kt (15 m/sec) displaced to the north. The TCFA was reissued at 142000Z, since supporting data did not, as yet, necessitate a warning.

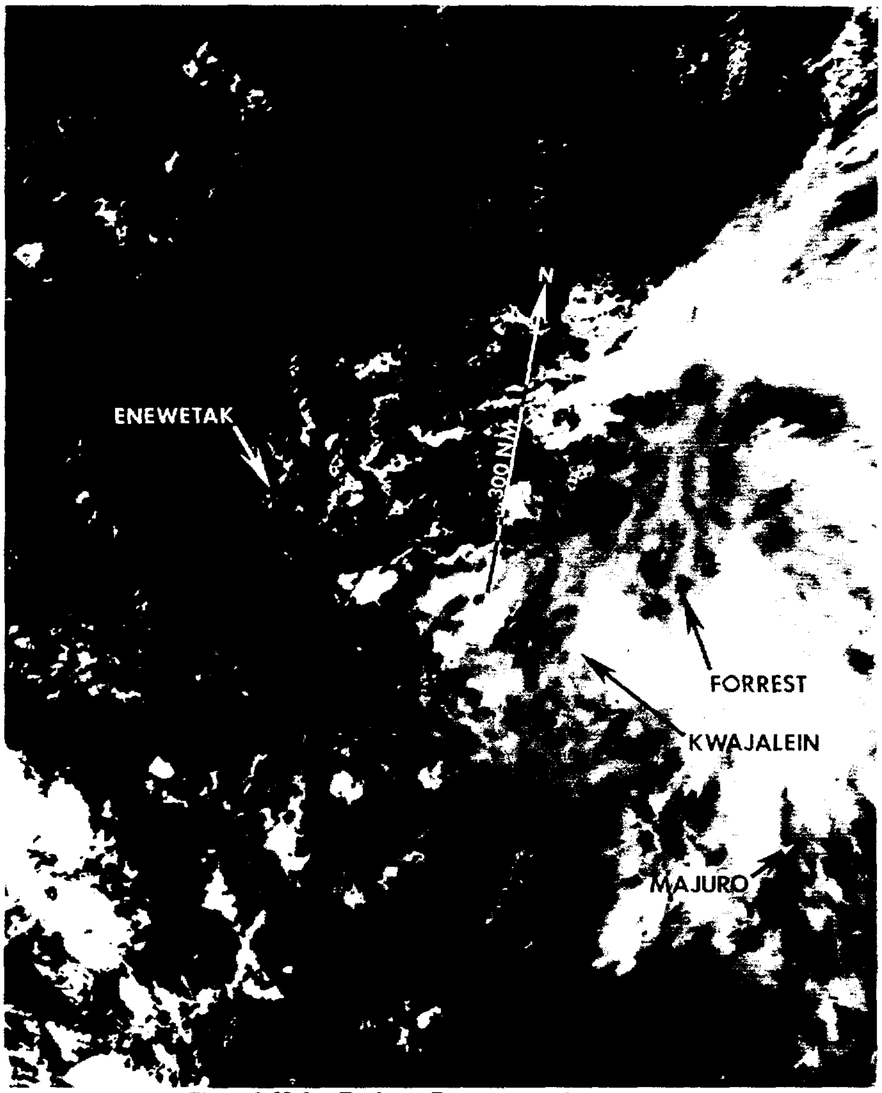


Figure 3-18-1. Typhoon Forrest organizing over the Marshall Islands (122311Z October DMSP visual imagery).

Aircraft reconnaissance on the 15th found a single circulation center; the MSLP had dropped to 1002 mb and maximum winds were 25 kt (13 m/sec). The (Dvorak) satellite intensity estimate at 151600Z of 45 kt (23 m/sec) prompted the first warning. The warning at 151800Z for Tropical Depression 18W, however, only mentioned maximum sustained winds of 30 kt (15 m/sec). The lower intensity on the warning was caused by the Typhoon Duty Officer placing more weight on the earlier aircraft reconnaissance information than the Dvorak analysis of infrared satellite imagery. Subsequent aircraft reconnaissance at 152126Z, however, proved otherwise. They reported maximum winds to be 55 kt (28 m/sec) with a MSLP of 988 mb and a closed, but thin, eyewall. At 160009Z, the aircraft observed 80 kt (41 m/sec). Figure 3-18-2 shows the stronger winds in the north semicircle of Forrest indicative of the tighter pressure gradient between the low pressure center and the subtropical ridge. The 160000Z warning upgraded Forrest from tropical depression to typhoon intensity with maximum sustained surface winds of 65 kt (33 m/sec). In retrospect, the initial warning was too conservative and the forecasters had waited too long for the aircraft reconnaissance to confirm the strong development indicated by the satellite data.

While moving northwestward at 16 to 18 kt (30 to 33 km/hr) over the next 24-hours, Forrest rapidly deepened. Nighttime aircraft reconnaissance on the 16th indicated Forrest had continued to deepen rapidly as the 700 mb heights fell 70 meters in less than three hours. Dvorak intensity estimate on satellite imagery at 161600Z indicated Forrest contained winds of 102 kt (53 m/sec). By 162105Z the 700 mb heights had dropped by 219 meters from 2840 meters to 2621 meters. The MSLP was 946 mb. Satellite imagery and aircraft intensities were in agreement, that Forrest had deepened rapidly over a very short time period. Forrest peaked at its maximum intensity of 100 kt (51 m/sec) at 170000Z (Figure 3-18-3). Two hours before this peak

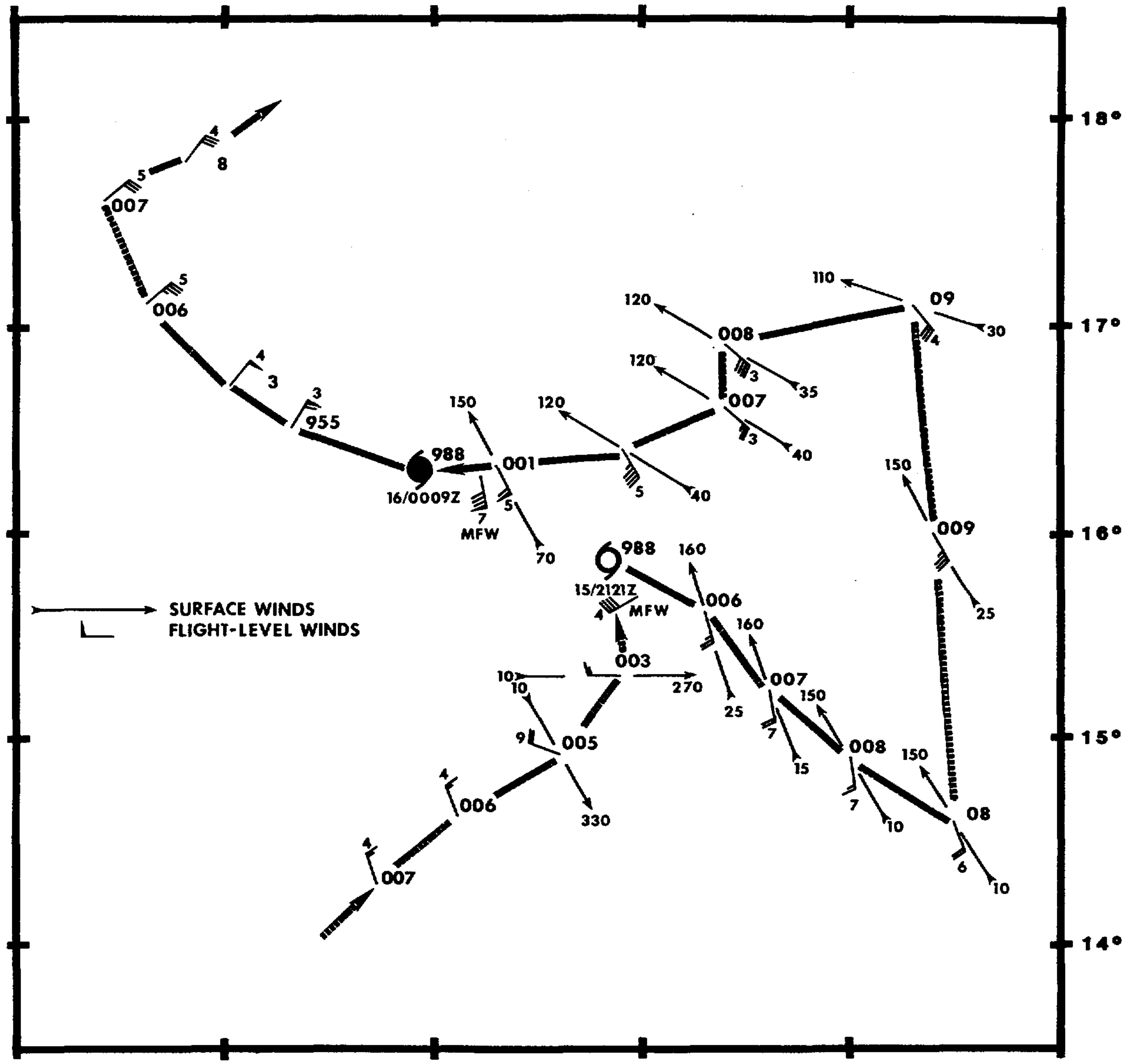


Figure 3-18-2. Plot of aircraft reconnaissance date from 152126Z to 160009Z October showing higher wind speeds to the north and east of the cyclone center. "MFW" represents the maximum observed flight-level winds and "MSW" represents the maximum observed surface winds.

Figure 3-18-3. Typhoon Forrest at maximum intensity of 100 kt (51 m/sec) with a small eye. With the sun low in the east, the cloud top topography is striking (162029Z October DMSP visual imagery).

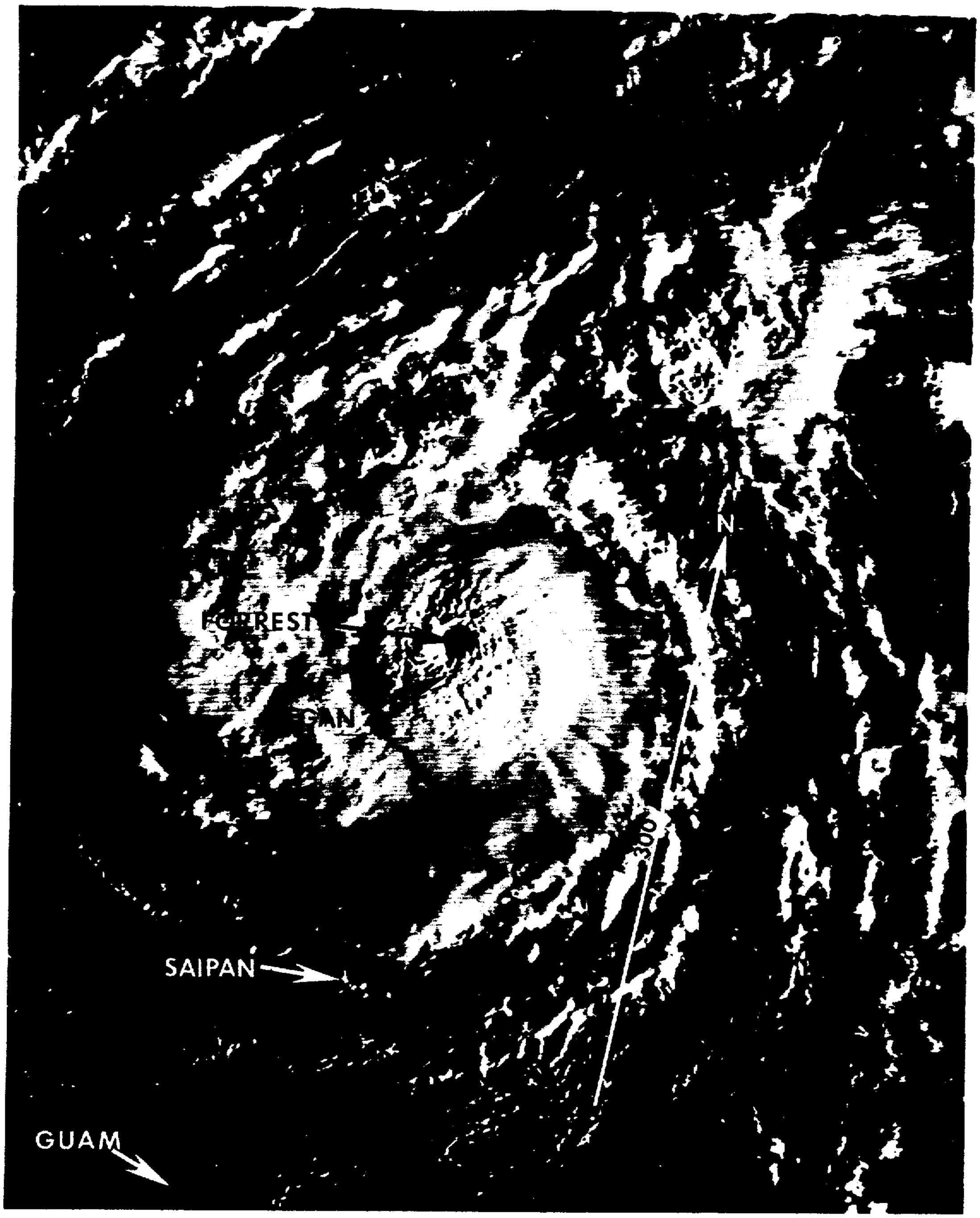
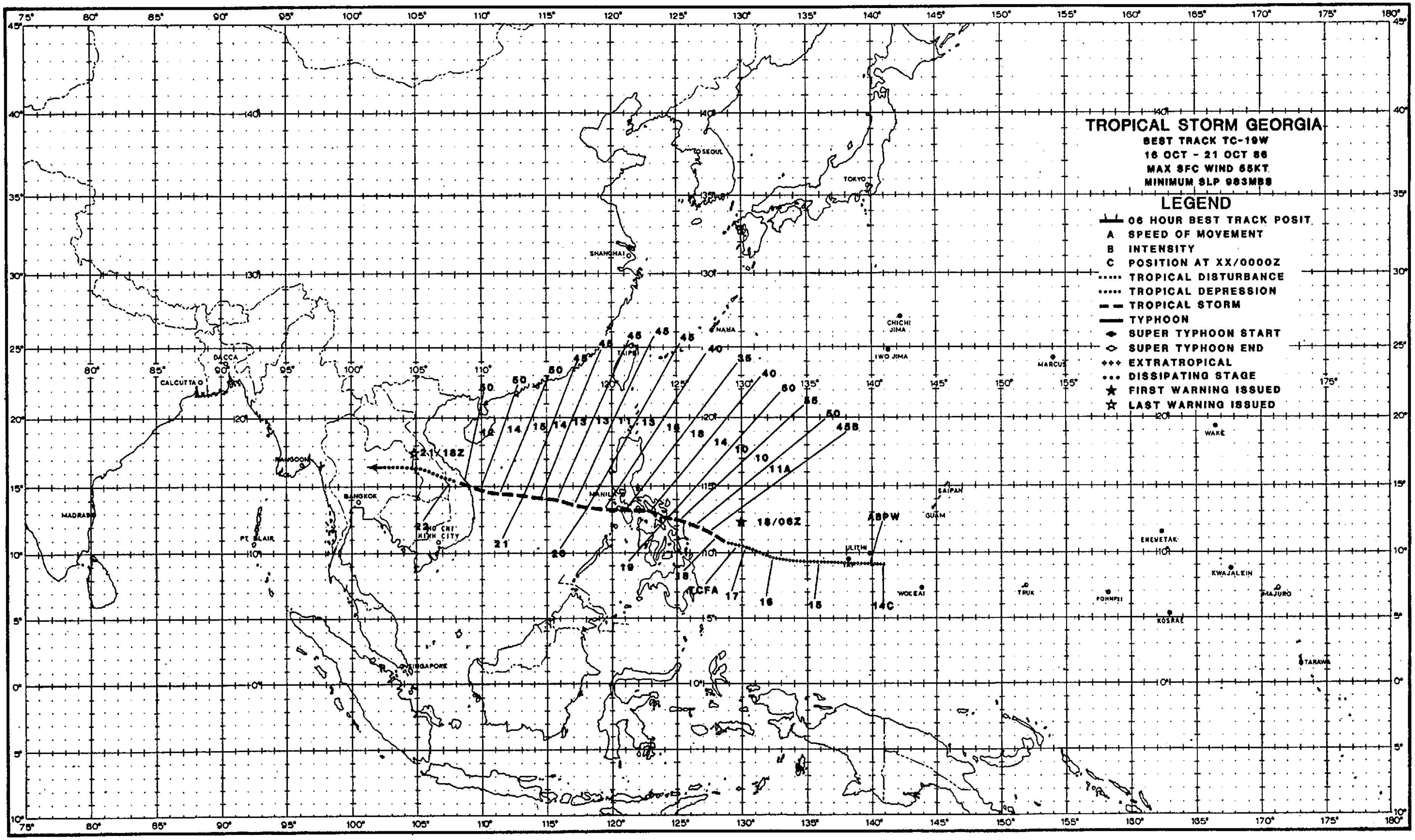


Figure 3-18-4. The thin cirrus clouds in the west semicircle indicate the beginning of the end for Forrest as it was becoming influenced by the stronger mid- to upper-level westerly flow. A short time later, Forrest began to move rapidly northeastward (180536Z October NOAA infrared imagery).

intensity, the island of Agrihan (located in the northern Marianas 270 nm (500 km) north of Guam) bore the brunt of Typhoon Forrest as it passed 10 nm (19 km) to the south. Fortunately, the island's 25 residents received no injuries even though only one building was left standing and two-way communications were destroyed. On the 21st of October, the Navy and Coast Guard joined forces and airlifted 1000 pounds of canned food, medical supplies and a two-way radio to the islanders.

At maximum intensity and just prior to recurvature, Forrest started elongating southwest to northeast and slowed to 5 kt (9 km/hr). JTWC had been expecting Forrest to recurve due to the break in the ridge since the first warnings on the system. The dynamic forecast aids were also in good agreement in this regard. The One-Way Interactive Tropical Cyclone Model (OTCM) provided the best guidance for speed and the Nested Tropical Cyclone Model (NTCM) had the best handle on direction.

Over the next 30-hours, Forrest began to very gradually weaken as it moved slowly around the western end of the subtropical ridge and started moving northeastward. Figure 3-18-4 shows Forrest's outflow restricted to the west due to the increasing westerlies aloft. By 191200Z, the system was beginning to accelerate northeastward at 23 kt (43 km/hr). Forrest completed transition to an extratropical cyclone and the final warning, indicating 55 kt (28 m/sec) intensity, was issued at 200600Z.



NOCC GUAM 3142/20 (NEW 5 - 80)

Typhoons Ellen (17W) and Forrest (18W) were already in progress, when Tropical Storm Georgia formed in the monsoon trough east of the Philippine Islands. The convective activity in the trough began to increase on the 14th of October, however it did not consolidate until the 18th.

First mention of Georgia as a tropical disturbance was on the Significant Tropical Weather Advisory (ABPW PGTW) of 140600Z. For the next four days, the large area of convection remained disorganized. By 17 October, satellite imagery (at 0300Z) indicated increased convective curvature and the (Dvorak) intensity estimate increased to 25 kt (13 m/sec). Aircraft reconnaissance later in the day closed off a weak, broad circulation center in the Philippine Sea 345 nm (639 km) northwest of Belau at 170655Z. A Tropical Cyclone Formation Alert was issued at 170821Z based on these data.

The (Dvorak) analysis of satellite imagery at 180052Z estimated a maximum wind of 30 kt (15 m/sec) (Figure 3-19-1). Aircraft reconnaissance in the area at 180543Z estimated surface winds of 45 kt (23 m/sec) with a minimum sea-level pressure of 991 mb. Based on the information provided by the aircraft reconnaissance crew, the first warning followed for Tropical Storm Georgia, valid at 180600Z.

At 181800Z, Georgia struck the central Philippine Islands with maximum winds of 55 kt (28 m/sec). The tropical cyclone weakened to 35 kt (18 m/sec) during the 16-hours it took to traverse the rugged central Philippine Islands. During this time, Georgia was forecast to remain south of the ridge and

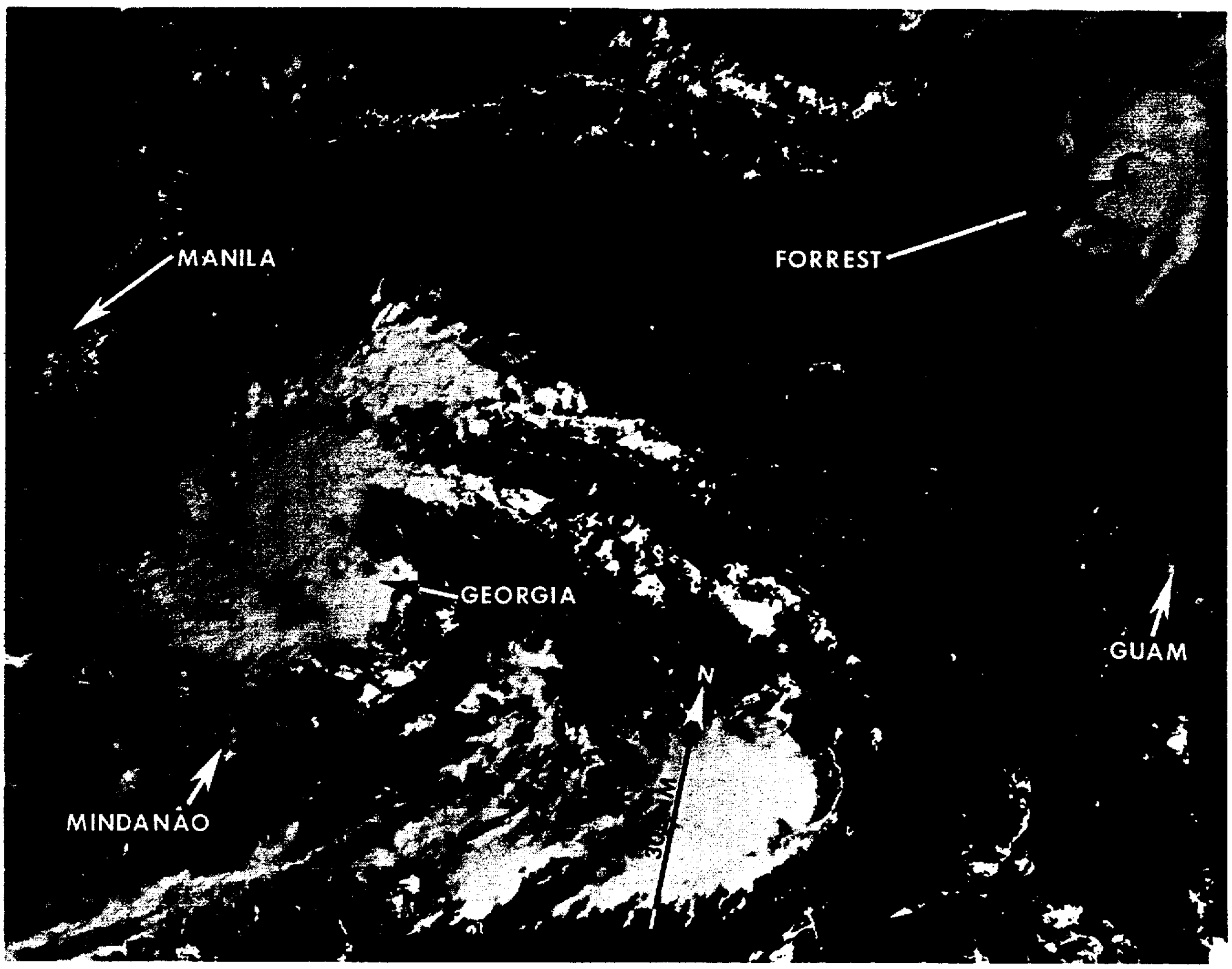


Figure 3-19-1. Georgia with (Dvorak) estimated winds of 30 kt (15 m/sec). Georgia was part of a multiple tropical cyclone outbreak that occurred in mid-October. Typhoon Forrest (18W) is located to the northeast of Tropical Storm Georgia on this satellite image. Typhoon Ellen (17W) was in the northern South China Sea and not visible on this pass (100052Z October DMSP visual imagery).

then move northwestward toward the island of Hainan. The forecast was in close agreement with the forecast aids for 180000Z through 181800Z which paralleled the low- to mid-level steering flow to the northwest. However, mid-level pressure surface heights rose across the northern South China Sea in the wake of Typhoon Ellen (17W), which had moved westward along the southern coast of mainland China. The 200000Z warning reflected a change in forecast philosophy and the track became more westerly with landfall in central Vietnam.

Upon entering the South China Sea, Georgia began to slowly reintensify. The final aircraft fix mission flew into Georgia on the 21st. On that flight, the reconnaissance aircraft reported severe turbulence in the convection surrounding Georgia's center (Figure 3-19-2). For the 12-hours prior to making landfall, Georgia's winds reached 50 kt (26 m/sec). The final warning was issued for Tropical Storm Georgia at 211800Z as the system made landfall and interacted with the rugged Annamitique mountains of central Vietnam.

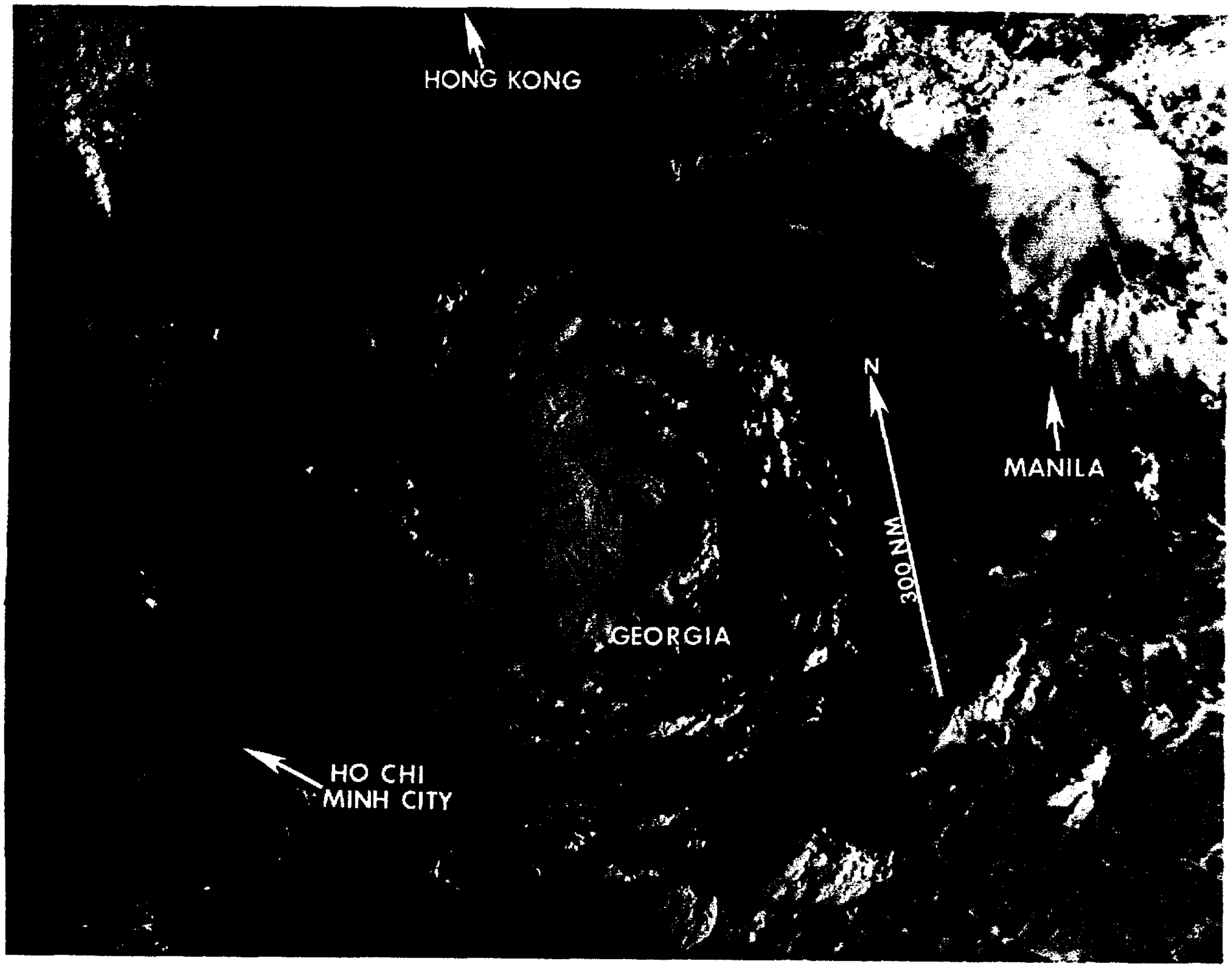
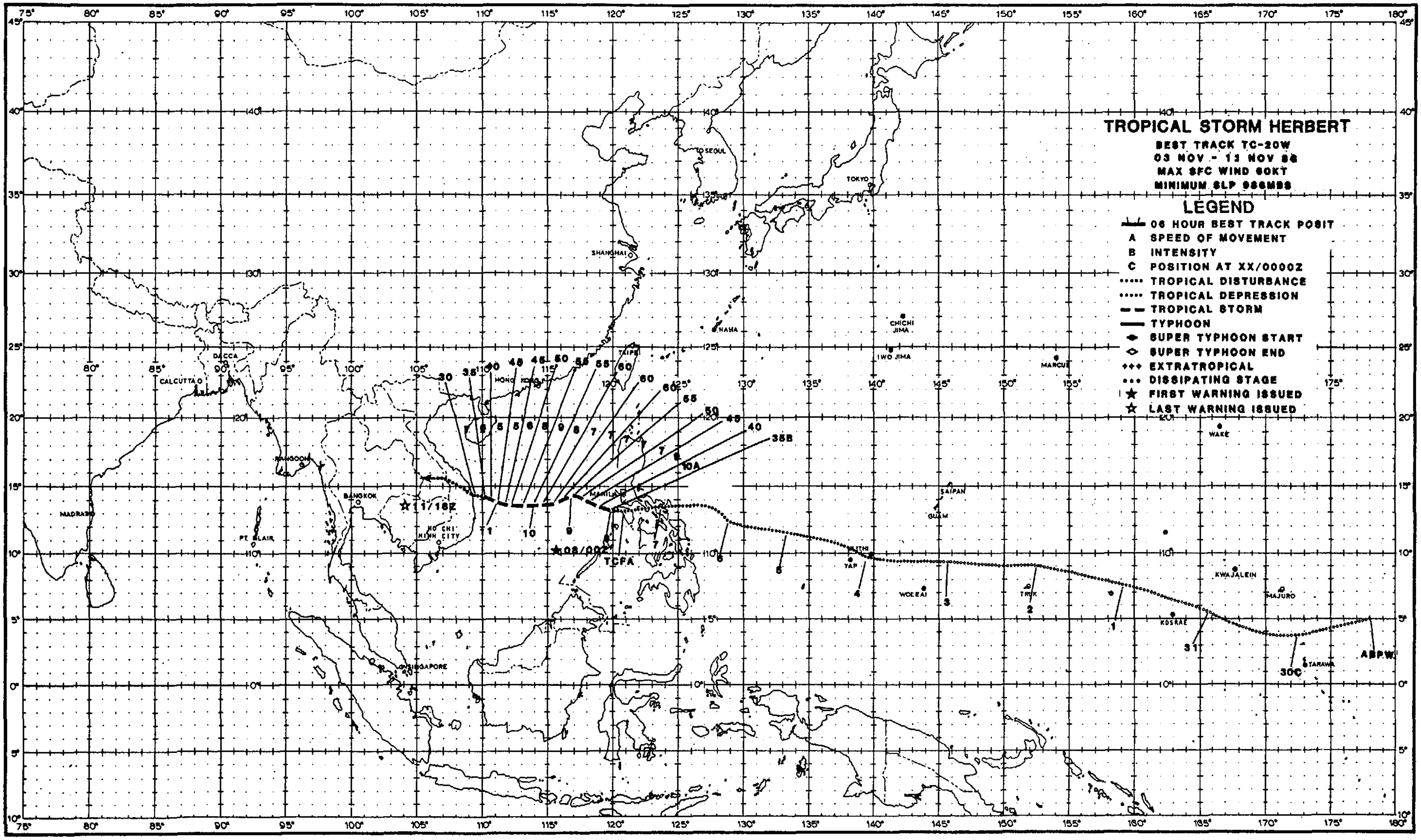


Figure 3-19-2. Tropical Storm Georgia after reintensifying in the South China Sea. The system made landfall 18-hours later and dissipated over the rugged mountains of Vietnam (210018Z October NOAA visual imagery).



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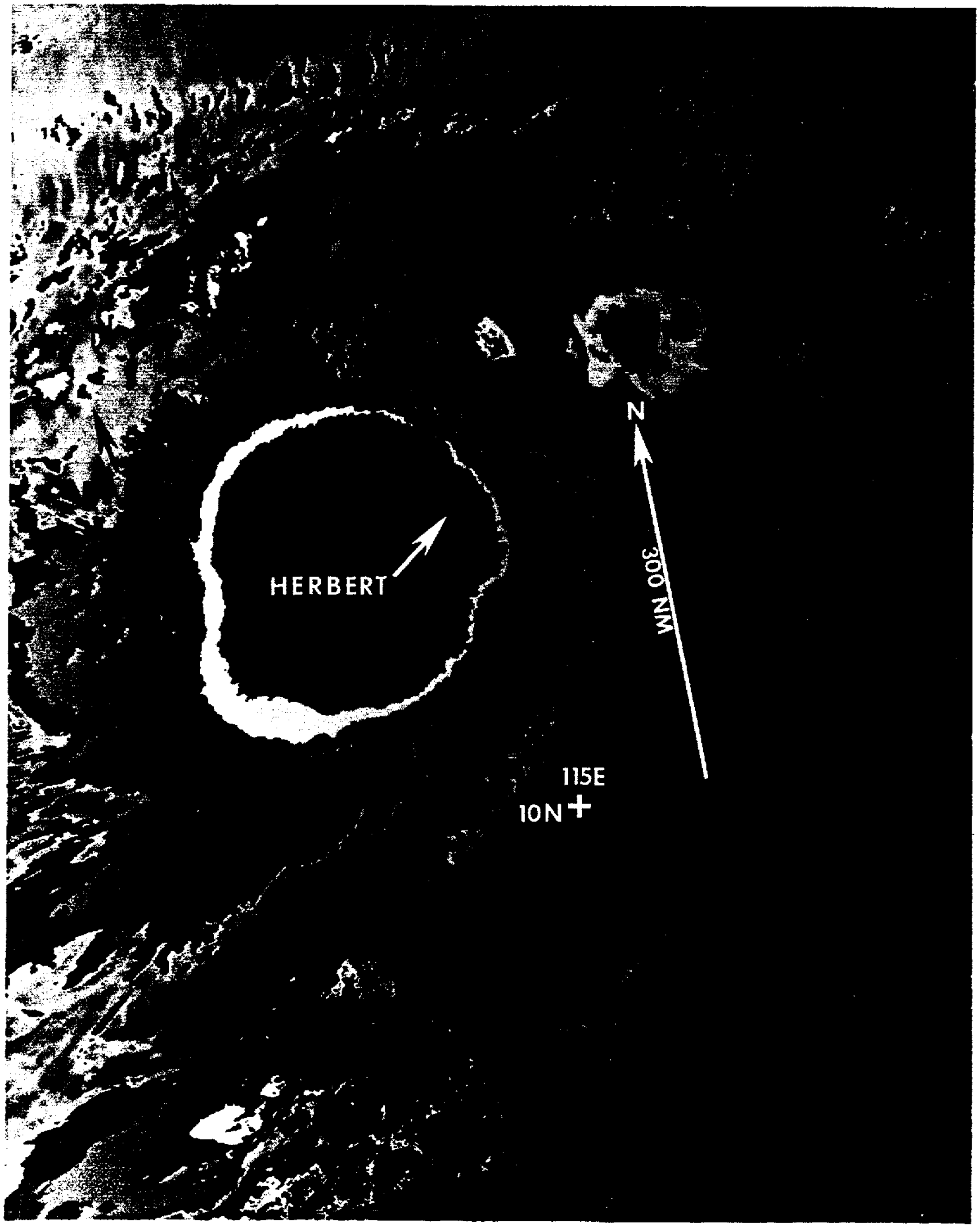
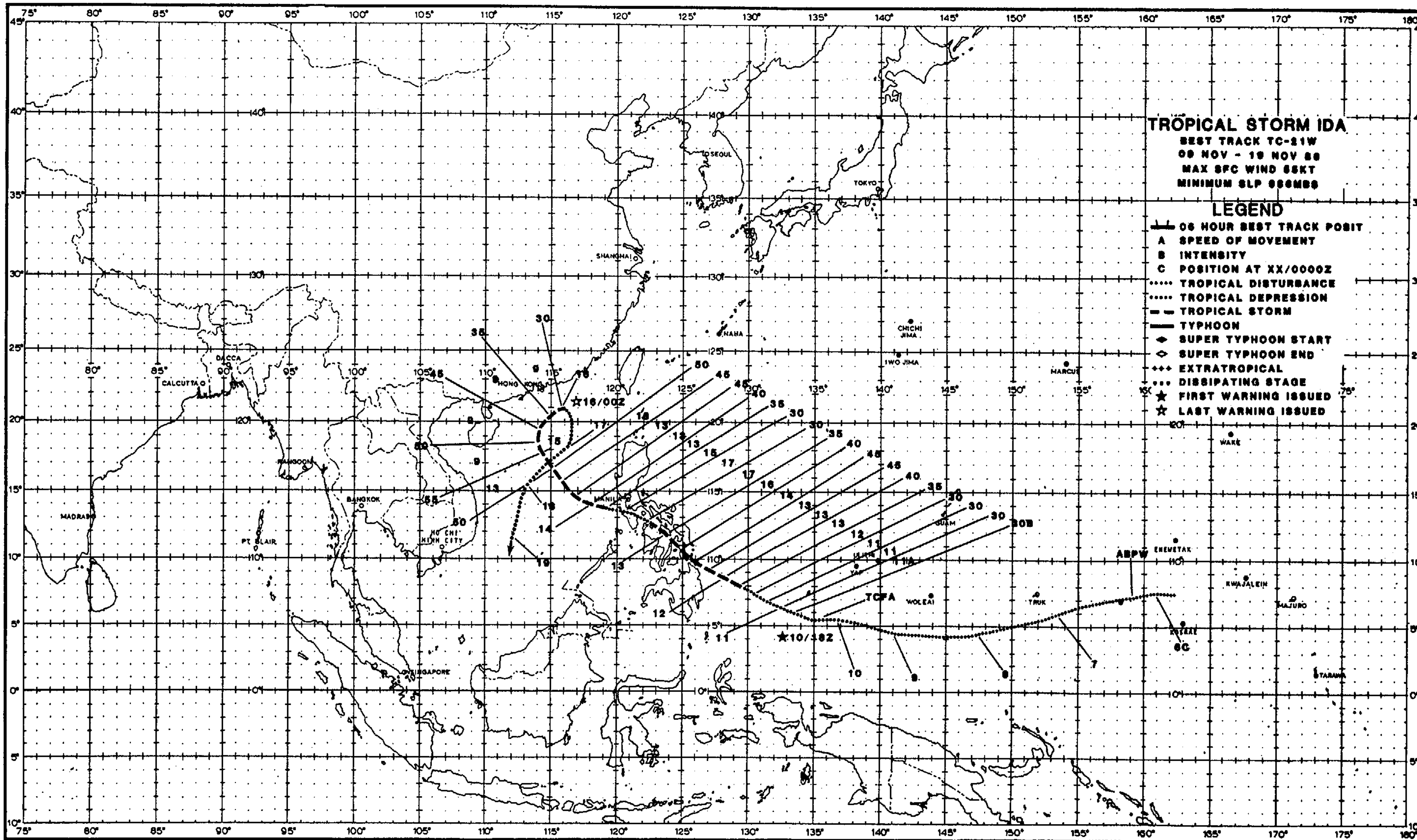


Figure 3-20-1. Herbert, as a tropical disturbance, tracked from east of the dateline across the western North Pacific, Philippine Sea and into the central Philippine Islands before reaching tropical storm intensity. The Significant Tropical Weather Advisory (ABPW PGTW) referred to this disturbance for a period of ten days (290600Z October to 070600Z November). The above NOAA imagery shows Tropical Storm Herbert near its maximum intensity of 60 kt (31 m/sec). On this specially enhanced infrared image note the small warm spot in the central dense overcast which is the eye. In the South China Sea, the strongest winds associated with Herbert persisted in the northeastern semicircle due to interaction with the northeast monsoonal flow from Asia. (092344Z November NOAA infrared imagery).



NOCC GUAM 3142/20 (NEW 5 - 80)

Tropical Storm Ida was the second of four tropical cyclones to develop during the month of November. This tropical cyclone presented unique forecast problems for JTWC as it interacted with strong northeasterly low-level flow near the coast of China.

Ida was first detected as a tropical disturbance in the near-equatorial trough on 6 November. Satellite and synoptic data indicated an upper-level anticyclone was present, but only a weak circulation existed near the surface. It was mentioned on the 060600Z Significant Tropical Weather Advisory (ABPW PGTW). By 9 November, the upper-level circulation was located near an area of broad-scale westerly flow approximately 500 nm (926 km) south of Guam. Tropical Storm Herbert (20W) and Typhoon Joe (22W) also developed in this same genesis area during the first half of the month. The excess cyclonic vorticity created by easterly winds south of the subtropical ridge and westerly winds near the equator enhanced development of the low-level circulation over the next 24-hours. Satellite imagery at 100129Z revealed a partially exposed low-level circulation center (Figure 3-21-1), prompting the issuance of a Tropical Cyclone Formation Alert, valid at 100600Z. Intense convection developed in the northeast quadrant during the evening hours of the 10th. The first warning on Ida, valid at 101800Z, was based on a satellite analysis of 35 kt (18 m/sec) winds using the Dvorak technique. Synoptic data indicated that Tropical Storm Ida lost its upper-level anticyclone, the main synoptic feature of its development, shortly after the first warning was issued. Aircraft reconnaissance flown on the morning of the 11th found a minimum sea-level pressure (MSLP) of 1004 mb, or the equivalent of 21 kt (11 m/sec) on the Atkinson-Holliday wind/pressure relationship.

In retrospect, the first warning may have been

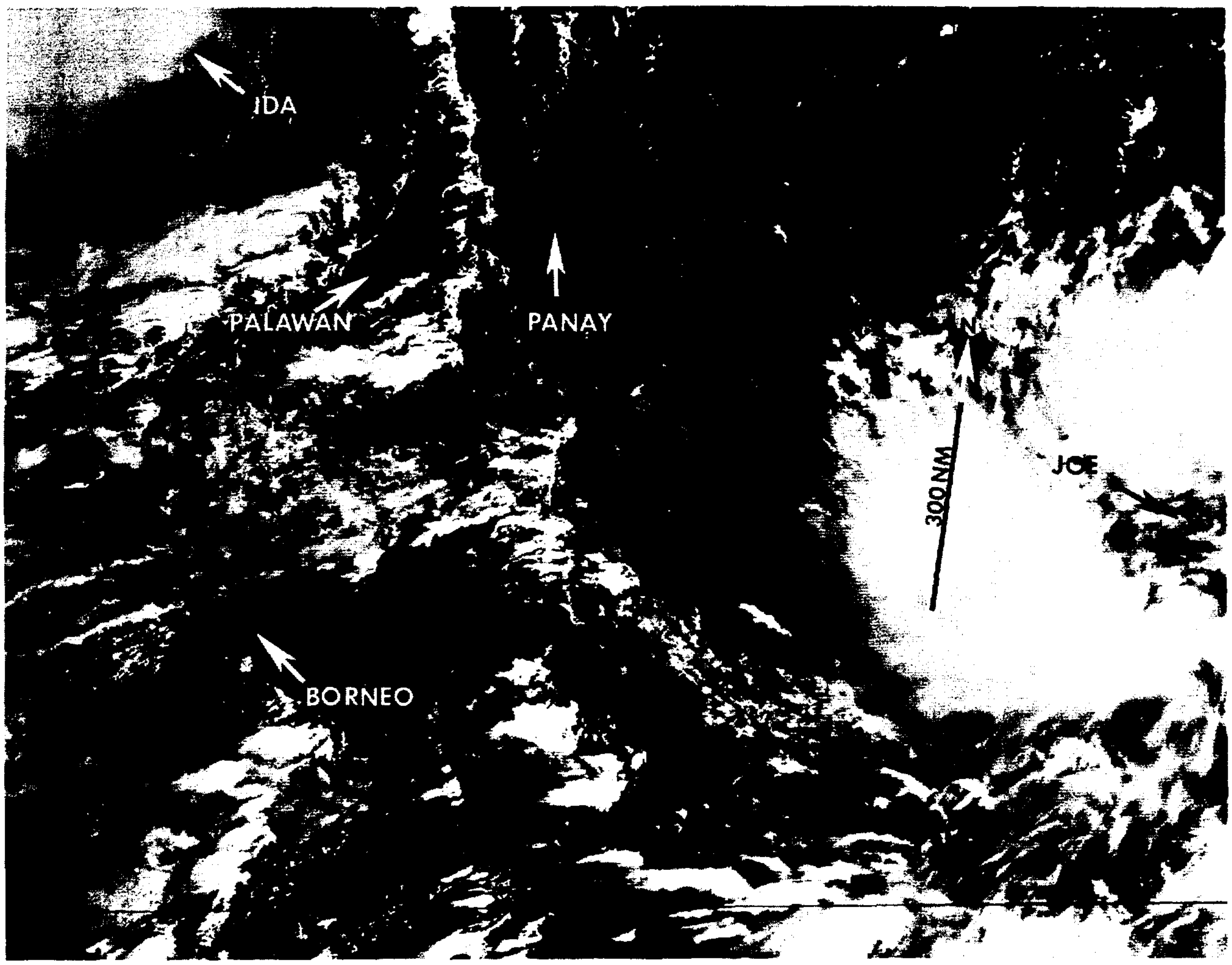


Figure 3-21-1. Tropical Storm Ida in the formative stage of development. Convective bands in the northern and western quadrants describe the upper-level anticyclone outflow that exists over the tropical disturbance (100129Z November DMSP visual imagery).

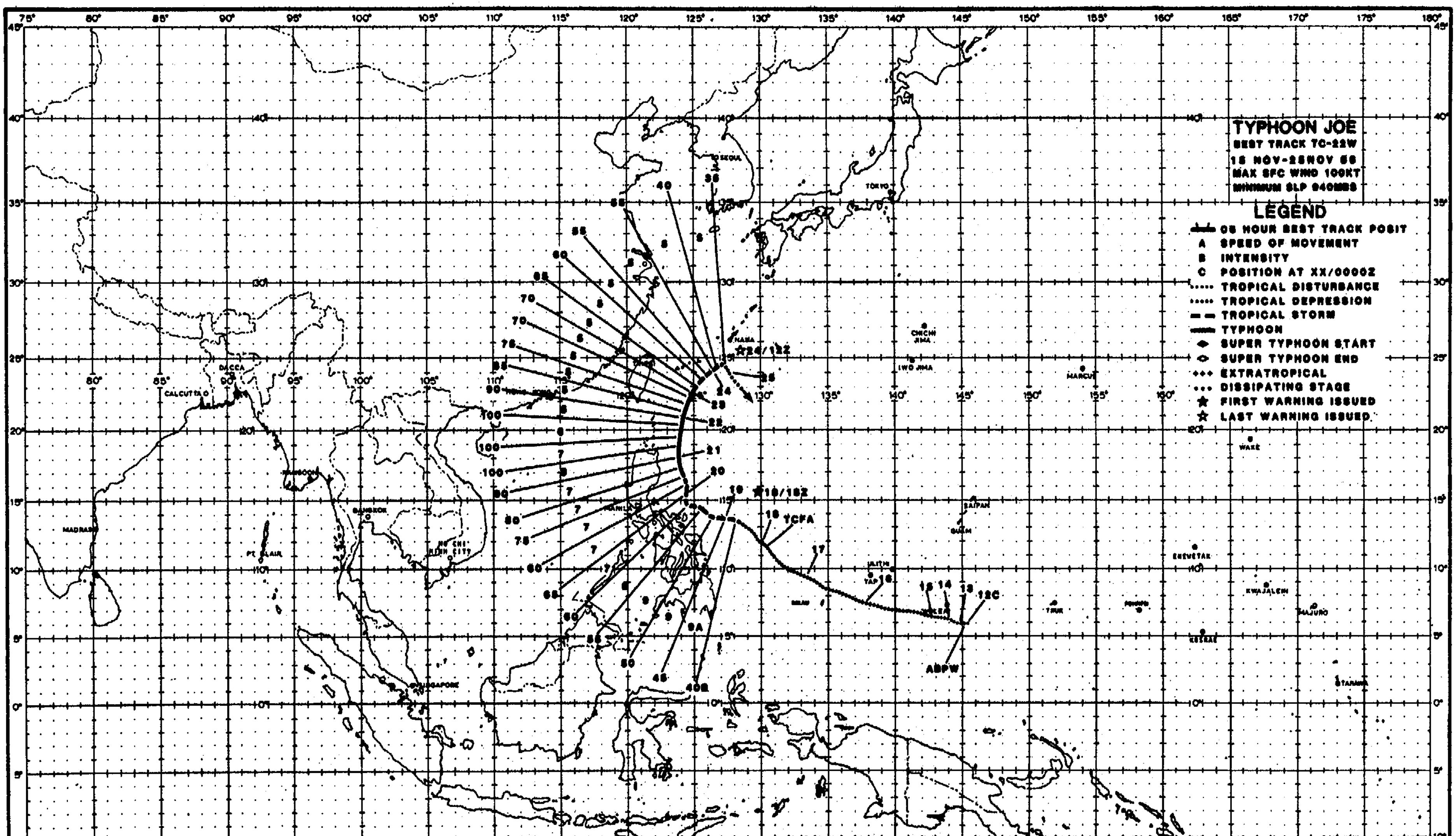
issued prematurely without enough data from synoptic and aircraft reconnaissance data to support an upgrade to tropical storm intensity. The initial warning was based on satellite analysis of a rapidly developing cloud system, which later proved to be inaccurate.

Tropical Storm Ida gradually intensified as it approached the Philippine Islands. Aircraft reconnaissance at 120223Z found a MSLP of 990 mb, or a drop of 14 mb in 24-hours. Ida accelerated as it traversed the Philippines and weakened slightly due to orographic effects. It followed nearly the identical track through the islands as Tropical Storm Herbert (20W) just six days earlier. Ida regained tropical storm intensity shortly after entering the South China Sea and reached its peak intensity of 55 kt (28 m/sec) early on the 15th (see Figure 3-21-2).

At this point Ida was influenced by the northeast monsoon winds off of mainland China. The One-Way Interactive Tropical Cyclone Model (OTCM) indicated the cyclone would continue its northward track for approximately 24-hours. JTWC forecasts followed this prognostic reasoning. Post-storm analysis indicated that Ida attempted to recurve around the subtropical ridge as the upper-level circulation sheared off to the northeast. However, the low-level circulation drifted eastward in apparent opposition to the surface wind flow. The cold air feeding into Ida caused it to undergo rapid extratropical transition. Also, the cold air behind the mid-level trough just north of Tropical Storm Ida merged with the warm air advected northward by the tropical cyclone, leading to the strengthening of the frontal boundary off the China coast. Ida became embedded in this frontal boundary. The final warning was issued at 160217Z. No loss of life or significant property damage was attributed to Ida.

The low-level eddy, which was the remnant of Ida, separated from the frontal boundary on 17 November and drifted southwestward in the South China Sea with the gradient-level flow. It persisted as a vortex on visual satellite imagery until 19 November.

Figure 3-21-2. Tropical Storm Ida near maximum intensity in the South China Sea (150129Z November DMSP visual imagery).



TYPHOON JOE
BEST TRACK TC-22W
MAX SFC WIND 100KT
LEGEND
06 HOUR BEST TRACK POSIT
A SPEED OF MOVEMENT
B INTENSITY
C POSITION AT XX/0000Z
TROPICAL DISTURBANCE
TROPICAL DEPRESSION
TROPICAL STORM
TYPHOON
SUPER TYPHOON START
SUPER TYPHOON END
EXTRATROPICAL
DISSIPATING STAGE
FIRST WARNING ISSUED
LAST WARNING ISSUED.
TCFA
ABPW
TOKYO
SEOUL
MANILA
GUAM
SAIPAN
WAKE
KWAJALEIN
MAJURO
YAP
IWO JIMA
BANGKOK
MADRAS

Typhoon Joe was the third of four tropical cyclones to reach warning status in the month of November. As a tropical disturbance, Joe became evident on satellite imagery on the 12th. JTWC mentioned it for the first time on the Significant Tropical Weather Advisory (ABPW PGTW) when it appeared as an area of enhanced convective activity 425 nm (787 km) south of Guam at 120600Z. The amount of convection and organization (Figure 3-22-1) increased very slowly as it moved west-northwestward. Synoptic data during this period indicated a weak low-level cyclonic circulation. Upper-level data indicated divergent flow aloft. The central convection began to consolidate and a Tropical Cyclone Formation Alert (TCFA) was issued at 172251Z. Satellite intensity analysis shortly after the TCFA issuance indicated surface winds of 35 kt (18 m/sec).

The initial aircraft vortex fix mission at 0213Z on the 18th located a 30 kt (15 m/sec) low-level circulation. The extrapolated minimum sea-level pressure (MSLP) was 1005 mb, which normally supports less than 30 kt (15 m/sec) winds (Atkinson and Holliday, 1978). By 181800Z, however, satellite imagery indicated increased development and the first warning was issued on Tropical Depression 22W. A circular eye 15 nm (28 km) in diameter was first observed by aircraft reconnaissance at 190046Z. Some elongation north-northeast/south-southwest was apparent on satellite imagery by 191800Z as Joe began to interact with a mid-latitude trough passing to the north. Three hours later, aircraft reconnaissance reported that Joe's eye had become elliptical and the MSLP had decreased to 976 mb. Typhoon intensity was reached between 191800Z and 200000Z as Joe began to

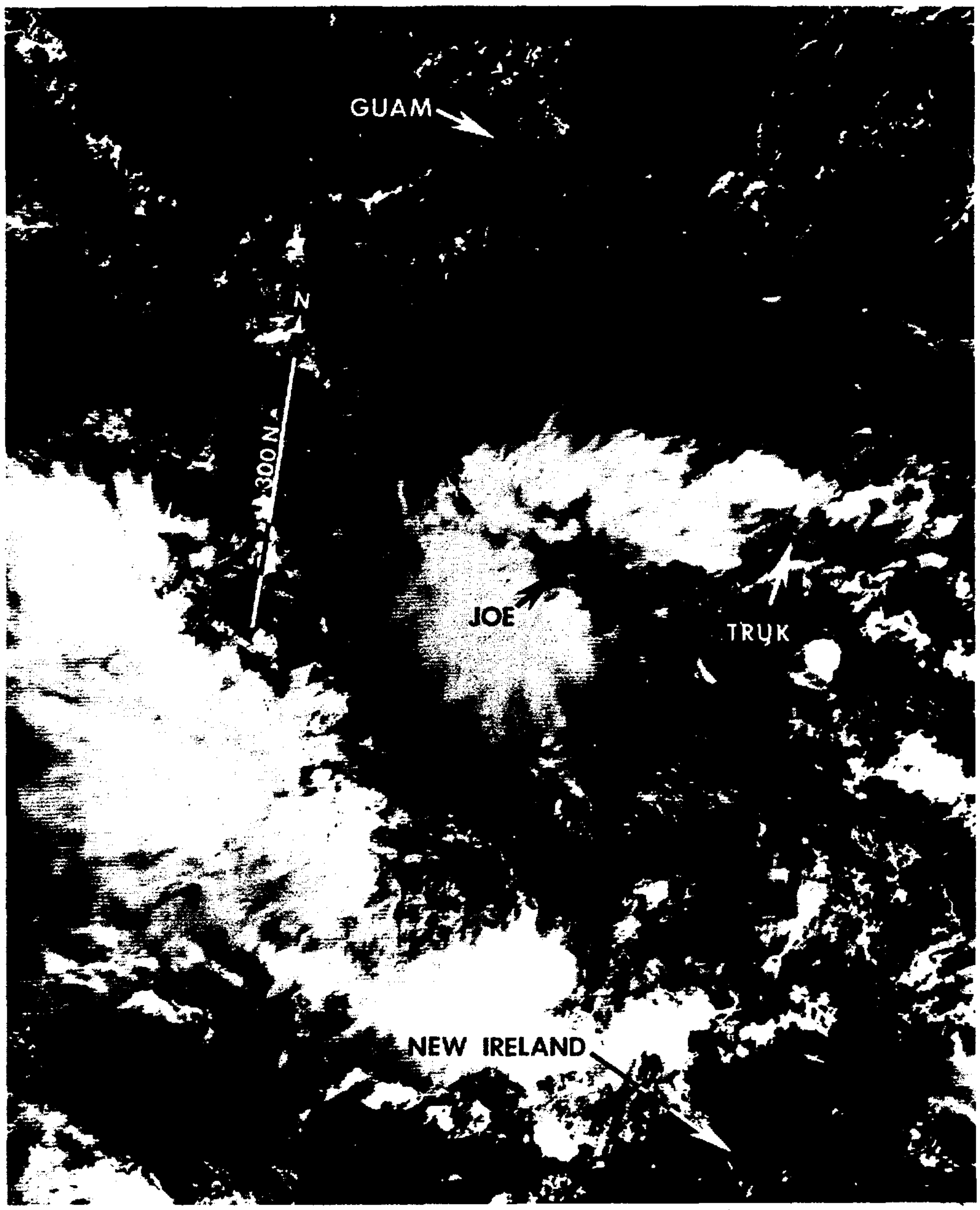


Figure 3-22-1. Typhoon Joe as an area of enhanced convection south of Guam (140008Z November DMSP visual imagery).

move northward around the periphery of the subtropical ridge to its east (Figure 3-22-2).

The first warning (181800Z) forecast Joe to move northwestward, just over the northeast corner of the island of Luzon in the Republic of the Philippines. The second through fifth warnings (from 190000Z to 191800Z) forecast a more westward track for Joe. These forecasts relied heavily on the dynamic guidance of the One-way Interactive Tropical Cyclone Model (OTCM) which indicated west-northwestward

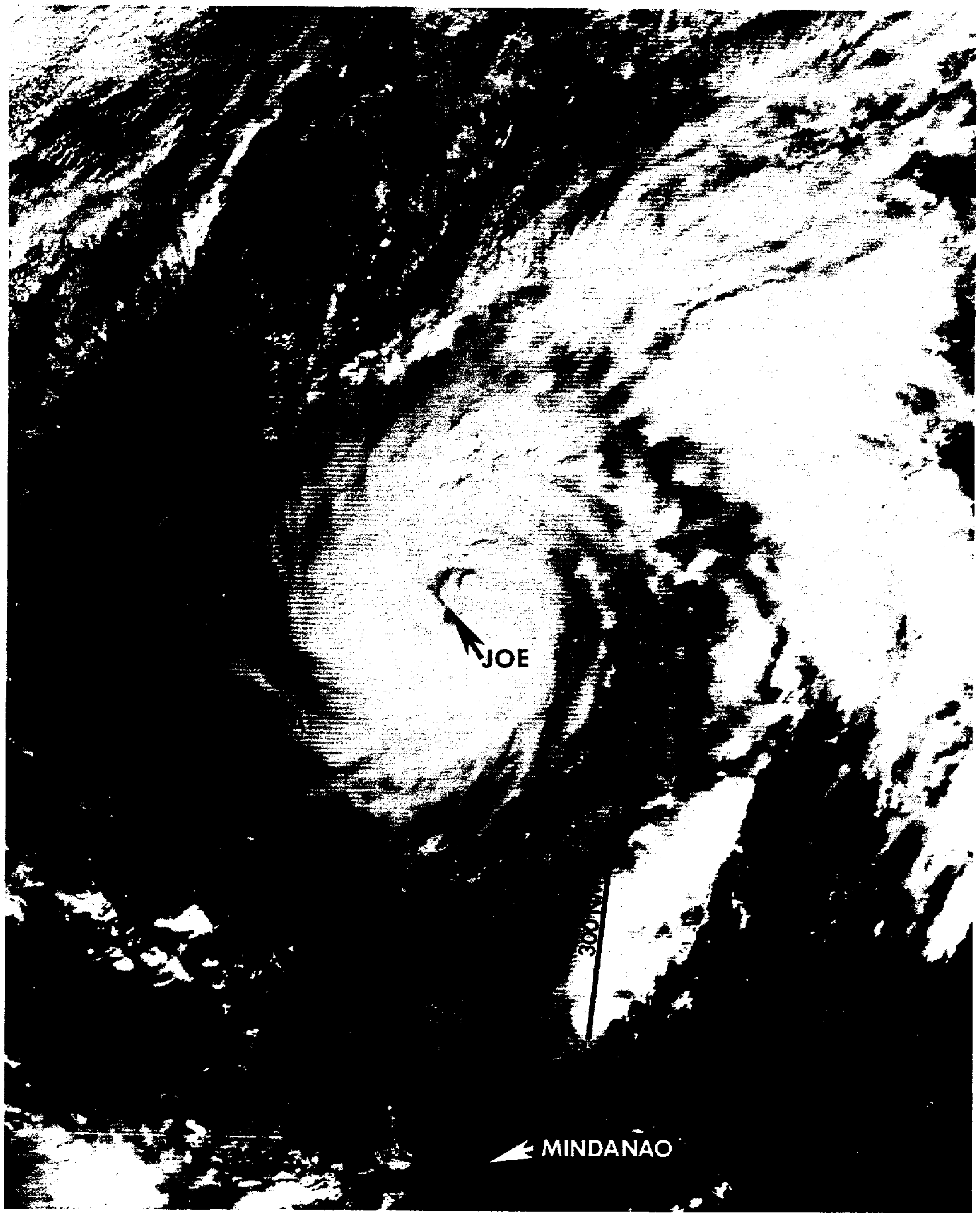


Figure 3-22-2. Typhoon Joe brushes by eastern Luzon (200128Z November DMSP visual imagery).

movement of Joe across central Luzon. However, the OTCM persisted in forecasting westward movement as late as 231200Z, three days after Joe had assumed a northerly track. This could possibly have been due to the model's inability to adequately handle the interactions between the typhoon and the strong northeasterly low-level flow from Asia. JTWC broke with the faulty OTCM guidance after the fifth warning and correctly forecast recurvature.

A ragged eye first became visible on satellite imagery at 0128Z on 20 November. Typhoon Joe continued to intensify, even as the strength of the mid- to upper-level southwesterly flow increased aloft. Joe continued to intensify and reached a peak of 100 kt (51 m/sec) maximum sustained surface winds at 210600Z.

As Joe continued to move northward around the western end of the subtropical ridge, the vertical shear on the system increased. The result was Joe's upper-level outflow became displaced to the northeast of the low-level leaving the exposed low-level circulation behind. The final warning was issued at 241200Z, since Joe no longer retained any persistent central convection. Only the residual low-level circulation persisted and was still evident on imagery through 242318Z (Figure 3-22-3).

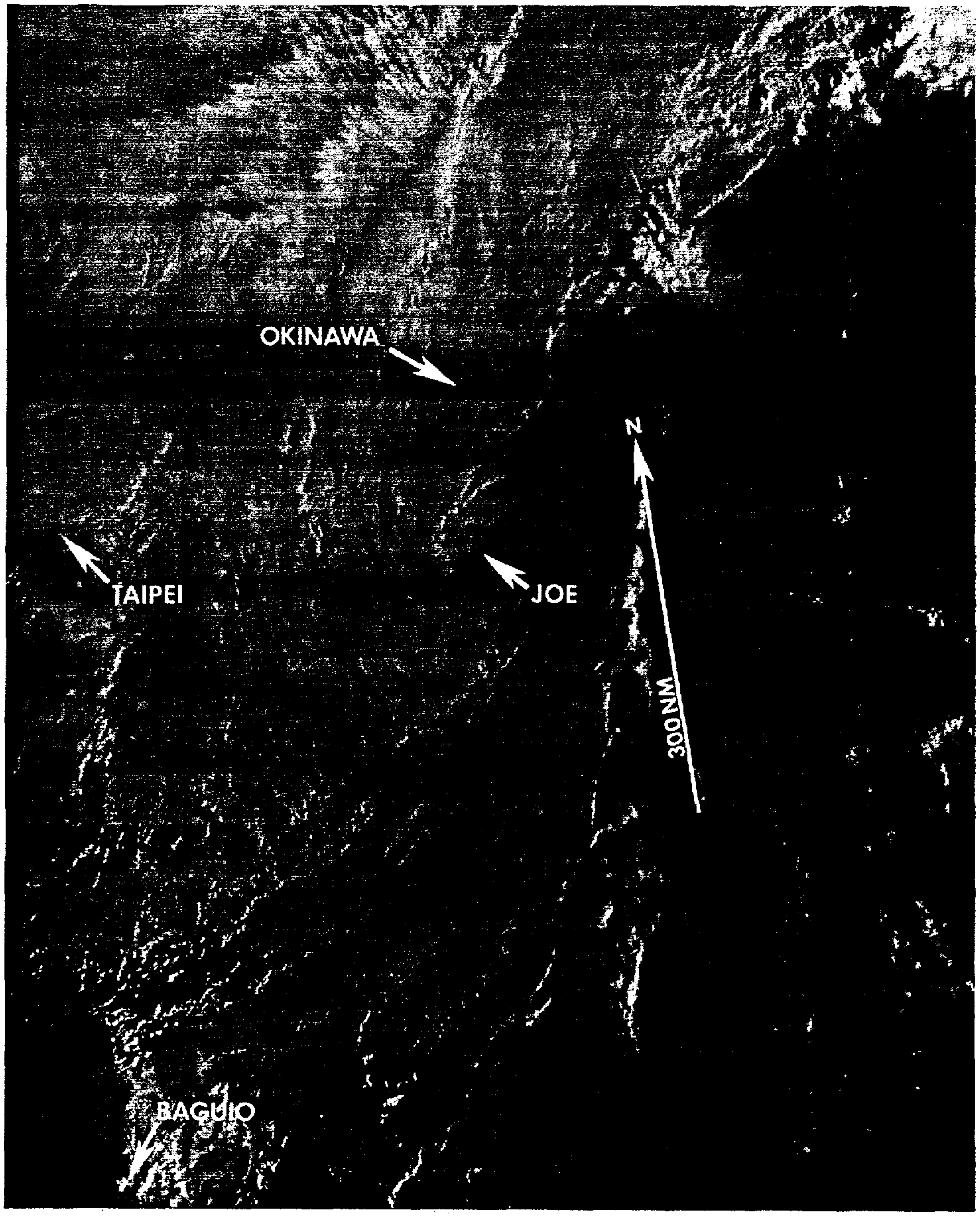
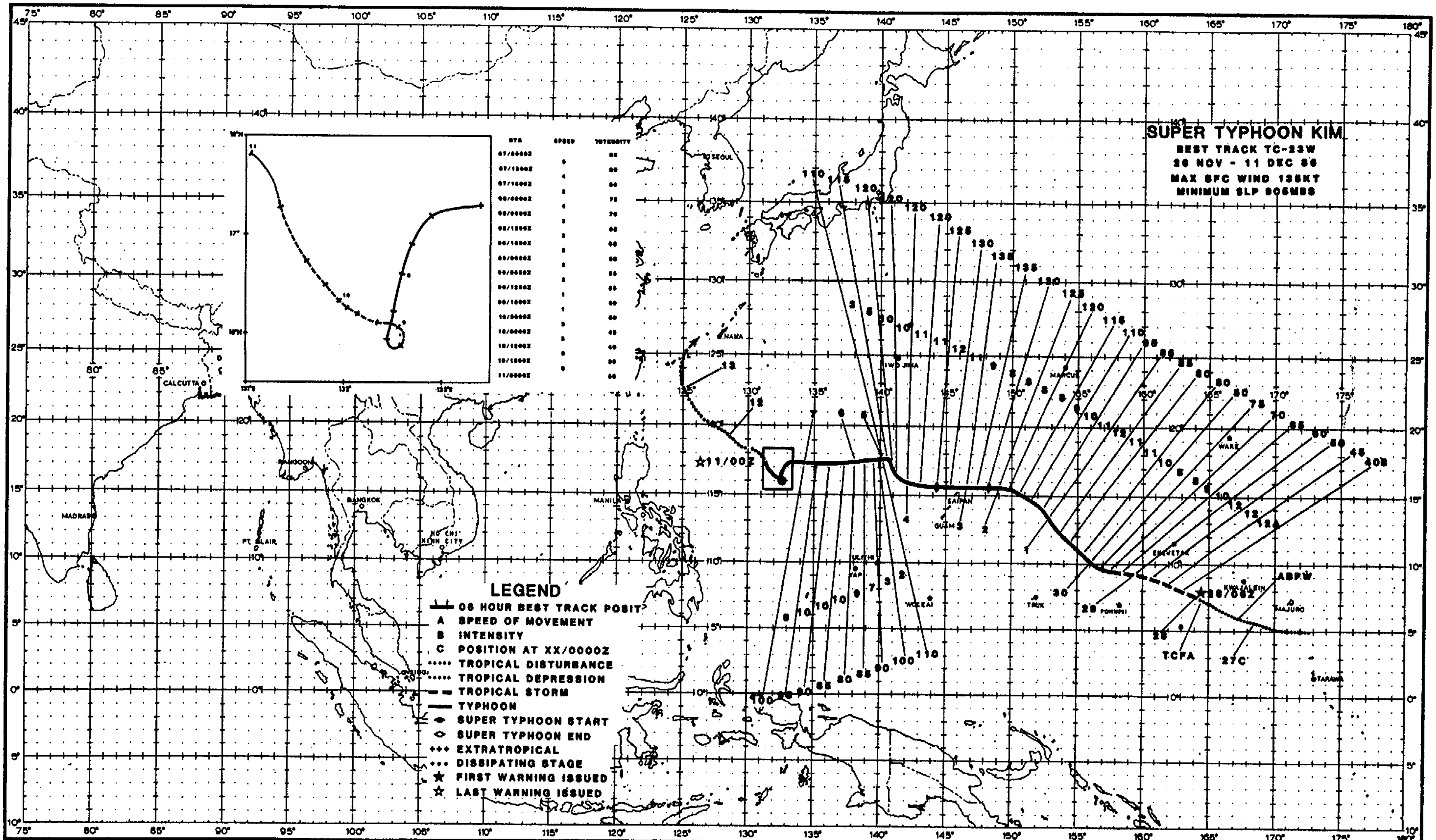


Figure 3-22-3. By 24 November, a residual low- level circulation was all that remained of Joe (242318Z November NOAA Visual imagery).



NOCC GUAM 3142/20 (NEW 5 - 80)

Super Typhoon Kim was a "midget" tropical cyclone that produced sustained winds of 135 kt (69 m/sec) with gusts to 165 kt (85 m/sec) and attained a minimum sea-level pressure (MSLP) of 905 mb. It was the fourth significant tropical cyclone that began in November, and was the first of four significant tropical cyclones in the month of December. Kim was the third super typhoon of the year and the first December super typhoon in twenty-two years since Super Typhoon Opal (December 1964). Fifty-two warnings were issued on Kim - more than any other tropical cyclone in 1986 except for Typhoons Vera (11W) and Wayne (12W). Thirty aircraft reconnaissance missions were flown on Kim, the most for any tropical cyclone in 1986. Included in these missions were five synoptic tracks and 45 center fixes. The information provided by the aerial reconnaissance platform was quite essential as Kim presented JTWC with track forecast problems at three different times.

Kim began, innocently enough, as a broad poorly organized area of convection near the dateline on the 26th of November. When convection persisted for 24-hours, JTWC first mentioned it on the Significant Tropical Weather Advisory (ABPW PGTW) at 270600Z. Maximum sustained winds were estimated at 10 to 20 kt (5 to 10 m/sec) and the MSLP was estimated at 1006 mb. Over the next 15-hours, outflow and convection increased significantly. Upper-level outflow was unrestricted in all quadrants and an upper-level anticyclone became well-established over the surface circulation center. The MSLP was estimated at 1005 mb. For these reasons JTWC issued a Tropical Cyclone Formation Alert (TCFA) at 272130Z, when the system was located about 360 nm (667 km) east of Pohnpei. Just nine hours later, at 280600Z, JTWC issued the first warning on Tropical Depression 23W based on a (Dvorak) intensity estimate of 35 kt (18 m/sec). At 281200Z, JTWC upgraded Tropical Depression 23W to Tropical Storm Kim based on continued intensification.

At 290126Z, the first aircraft reconnaissance mission closed off the surface circulation center 145 nm (269 km) north-northeast of Pohnpei. The Aerial Reconnaissance Weather Officer reported that an elliptical eye was beginning to form, which was open to the northwest. This first penetration found maximum 700 mb winds of 65 kt (33 m/sec) and a 700 mb height of 2921 meters, which corresponds to an MSLP of about 980 mb. The second penetration, 90 minutes later, reported maximum surface winds of 80 to 85 kt (41 to 44 m/sec). The 290600Z warning upgraded Kim to typhoon status.

From 261800Z through 291200Z (warning number 6), Kim tracked toward the west-northwest following a basic under-the-ridge scenario. At 291800Z, the eastward movement of a mid-latitude trough weakened the subtropical ridge. This caused Kim to move northwestward. The weakness in the ridge was misinterpreted by JTWC as a "break" in the ridge. At 010000Z, JTWC altered Kim's forecast track from an under-the-ridge scenario to a through-the-ridge scenario based on this break. Kim's track changed from anticyclonic to cyclonic, as Kim continued to track toward the northwest. As Kim reached the inflection point, it began to intensify at a rate slightly greater than expected from the normal Dvorak curve of one "T-number" per day. Kim's intensity increased from 85 kt (44 m/sec) at 010000Z to 135 kt (69 m/sec) by 022100Z.

The first, of three, major track forecasting problems arose when aircraft reconnaissance at 021105Z verified prior satellite imagery indications that Kim was moving westward. The mid-level ridge to the north strengthened as the low- to mid-level trough moved off to the east. Because of the significant forecast track change on Kim, an abbreviated warning message was sent out at 022100Z, since Kim immediately became a threat to Saipan.

At about 030400Z, Super Typhoon Kim, with its peak winds of 135 kt (69 m/sec), passed about 18 nm (33 km) to the north of Saipan. Kim inflicted

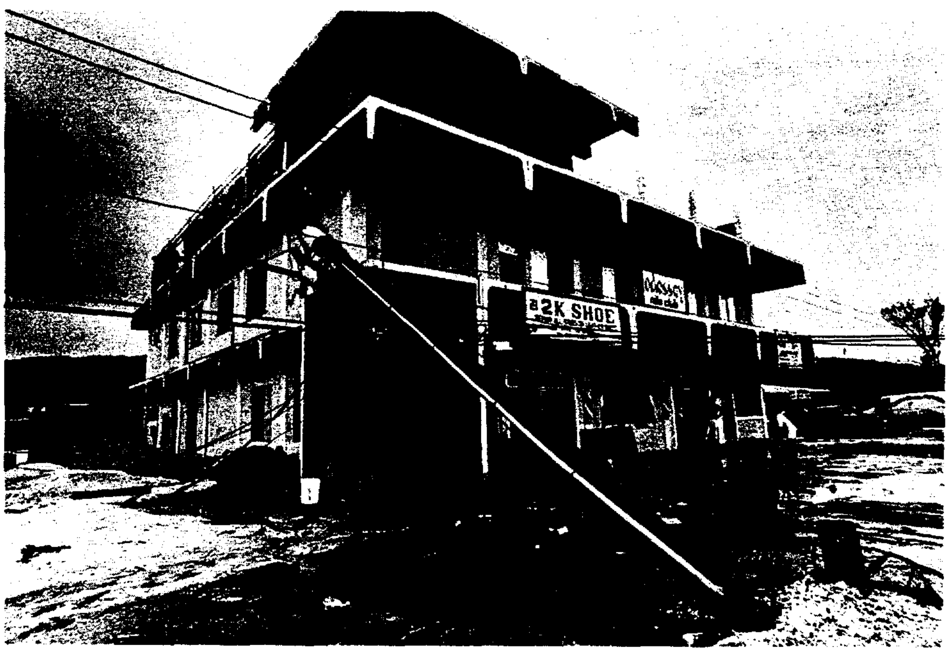


Figure 3-23-1. One of the many downed telephone poles leans against a shoe store in Garapan, the major city of Saipan, in the aftermath of Kim (Photo provided courtesy of Guam Publications, Inc.).

substantial damage to Saipan, leaving the entire island without electricity and water. An estimated one-third of all power poles were down (see Figure 3-23-1), hundreds of people were left homeless, 14 people were injured, mainly due to flying glass, and one (heart attack) fatality was reported. Damages (Figure 3-23-2) were estimated at about 15 million dollars by the Governor of Saipan. A team of U.S. Navy Construction Battalion personnel (Seabees), engineers from the U.S. Navy Public Works Center (Guam) and electrical generators were sent to Saipan to get the island's essential power system back on-line.

Kim continued tracking westward until 040000Z (Figure 3-23-3). Afterward, it began moving northwestward. This presented the second major forecasting problem with Kim. JTWC had followed the One-Way Interactive Tropical Cyclone Model (OTCM) guidance and repeatedly forecast recurvature. A synoptic track flown between 040500Z and 041200Z indicated a "break" in the subtropical ridge approximately 135 nm (250 km) southwest of Iwo Jima. The forecast looked good, but for the second time an unforecasted major directional change in the track occurred. Once again, this was not a "break" in the ridge, but merely a weakness that would cause the tropical cyclone to take a "step" toward the northwest and then return to a the westward track; as the mid-latitude trough moved north and then east of the system.

At 071200Z, Kim abruptly changed track and began moving toward the south along the leading edge of a modifying polar air mass moving off the Asian landmass. At the same time, the entrainment of cold air and increased vertical shear started to weaken the tropical cyclone. Aircraft reconnaissance at 081542Z, 082130Z and 090000Z documented this trend and Kim was subsequently downgraded to tropical storm intensity at 090000Z. By 090600Z, Kim's intensity was down to 55 kt (28 m/sec), and forty-two hours later, at 110000Z, to 30 kt (15 m/sec). After three days of erratic movement, Kim was further downgraded to a tropical depression. The final warning was issued at 110000Z as the system dissipated over water. The remains of Kim tracked west-northwestward and dissipated over the Philippine Sea 300 nm (556 km) east of the island of Luzon.

Figure 3-23-2. Many structures were extensively damaged by wind and water (Photo courtesy of Guam Publications, Inc.).

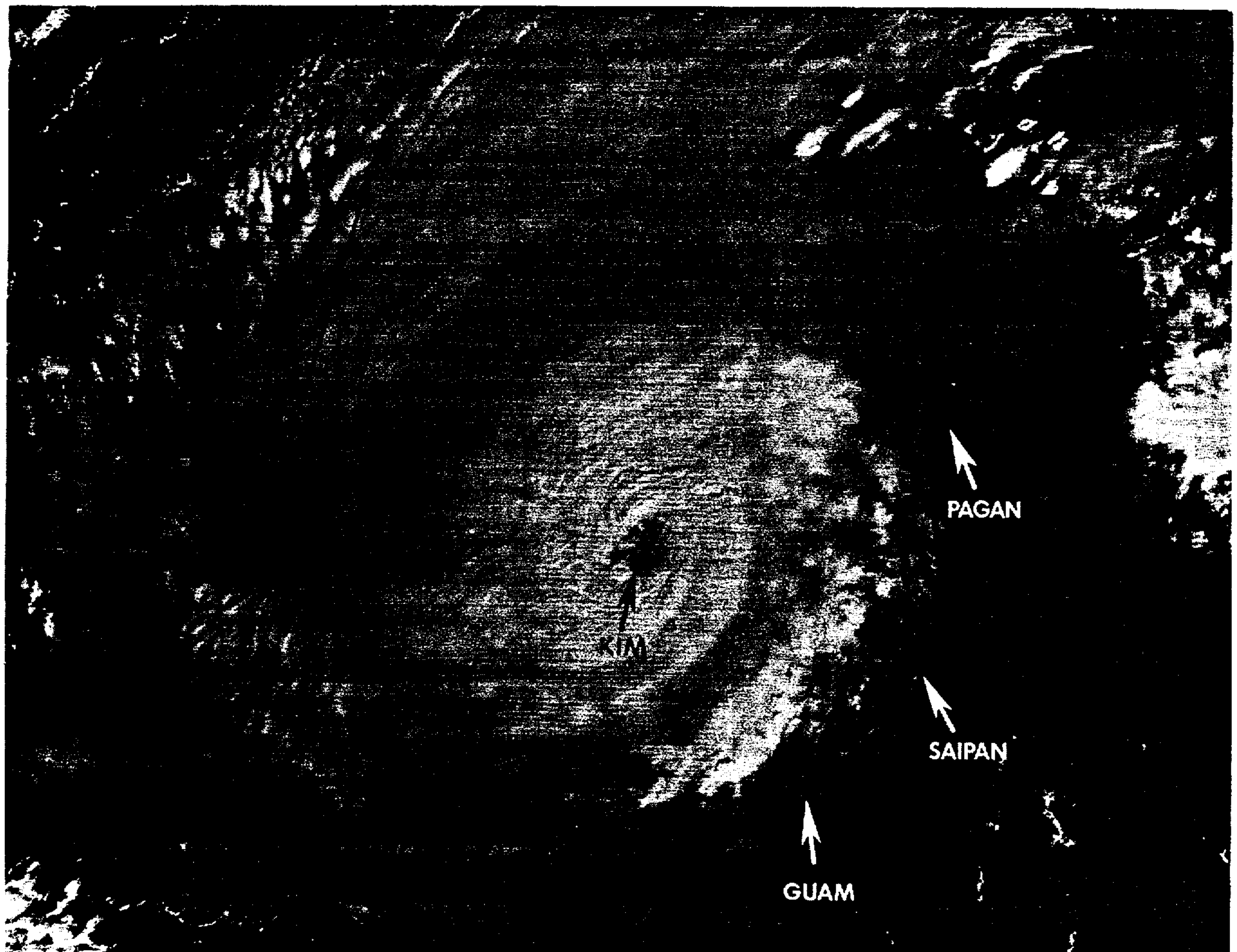
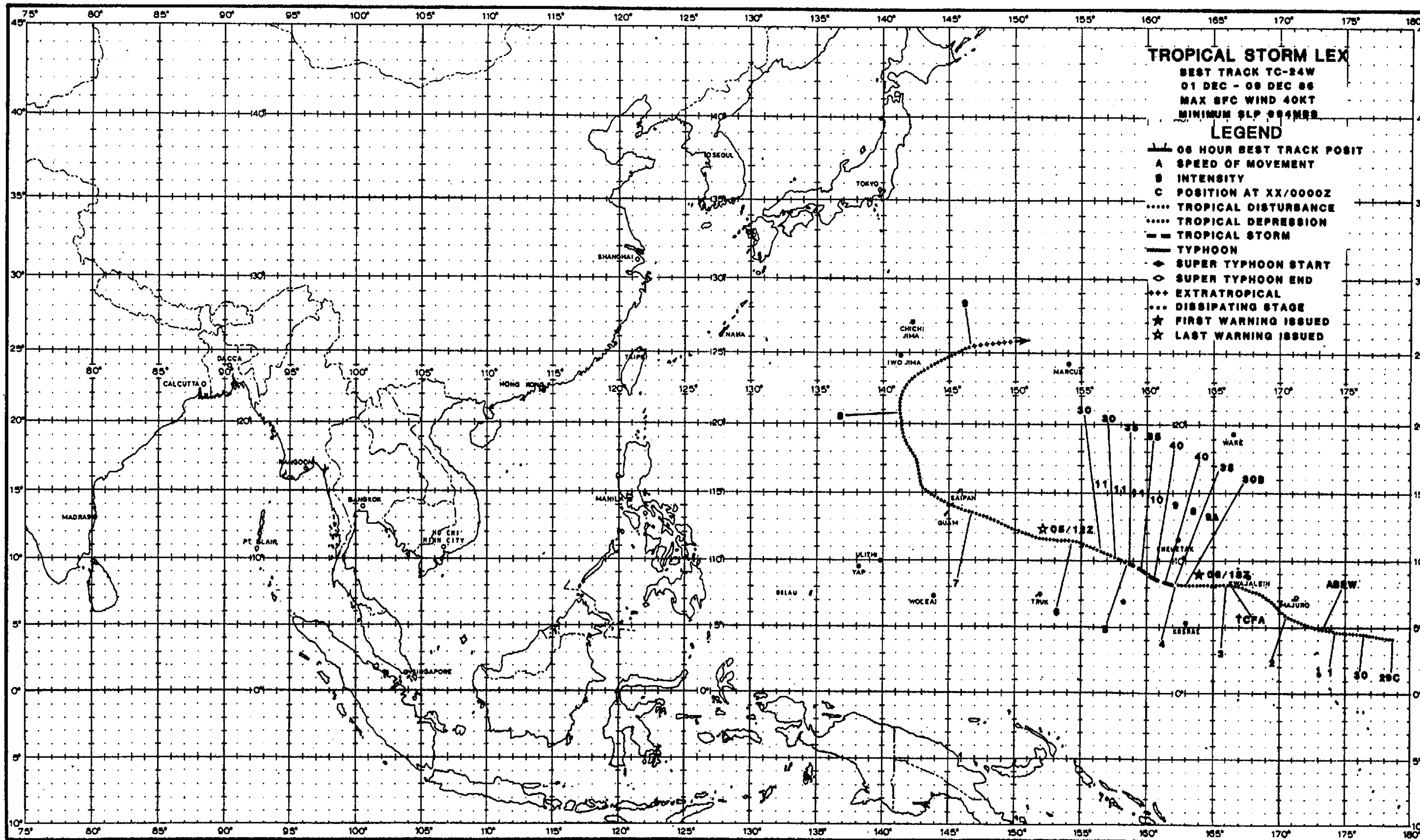


Figure 3-23-3. A day after damaging Saipan, Super Typhoon Kim was still on a westward track (040004Z December DMSP visual imagery).



NOCC GUAM 3142/20 (NEW 5 - 80)

Tropical Storm Lex was the first of three significant tropical cyclones to develop in the month of December. Initially, Lex developed rapidly in the wake of Super Typhoon Kim (23W) and presented a threat to Guam. Significant further development was inhibited by Kim (23W) and a mid-latitude trough, although a brief flare-up of convection occurred just before Lex passed through the southern Marianas.

Lex first appeared as a small mass of convection about 300 nm (556 km) to the east-southeast of the Kwajalein Atoll in the Marshall Islands at 301200Z November. The convection rapidly increased. Upper-level organization and low-level inflow also increased over the next 18-hours. For these reasons, Lex was initially placed on the Significant Tropical Weather Advisory (ABPW PGTW) at 010600Z December.

The tropical disturbance continued to show potential for development and at 022345Z, it became the subject of a Tropical Cyclone Formation Alert (TCFA). The convection became more centralized, prompting JTWC to issue the first warning on Tropical Depression 24W at 031800Z. Upper-level organization continued to improve, as satellite imagery indicated good banding features to the north and south. Increased satellite (Dvorak) intensity estimates resulted in an upgrade from Tropical Depression 24W to Tropical Storm Lex at 040000Z on the second warning.

Lex was first fixed by aircraft reconnaissance at 040537Z. The Aerial Reconnaissance Weather Officer reported surface winds of near 45 kt (23 m/sec), and fixed the surface center further to the east of the previous (040000Z) warning position, which was based on satellite data, and 85 nm (157 km) east of the 040600Z forecast position. This led JTWC to relocate Lex's position on the 040600Z warning.

Although forecast to reach typhoon intensity within 48-hours, it had already attained its peak intensity by 040600Z. The combination of an eastward moving trough and the proximity of Kim (23W) to the northwest, greatly inhibited Lex's upper-level outflow.

Aircraft reconnaissance indicated a tilt toward the west between the surface center and the upper-level center and a possible secondary center about 30 nm (56 km) to the northwest of Lex. As evidenced in visual satellite imagery at 042344Z (Figure 3-24-1), Guam was between Super Typhoon Kim (23W) (to the northwest) and Tropical Storm Lex. Lex continued to decrease in convection and organization. A nighttime aircraft reconnaissance fix mission scheduled for 051200Z found 700 mb westerlies throughout the area and no sign of a closed circulation. For these reasons, Tropical Storm Lex

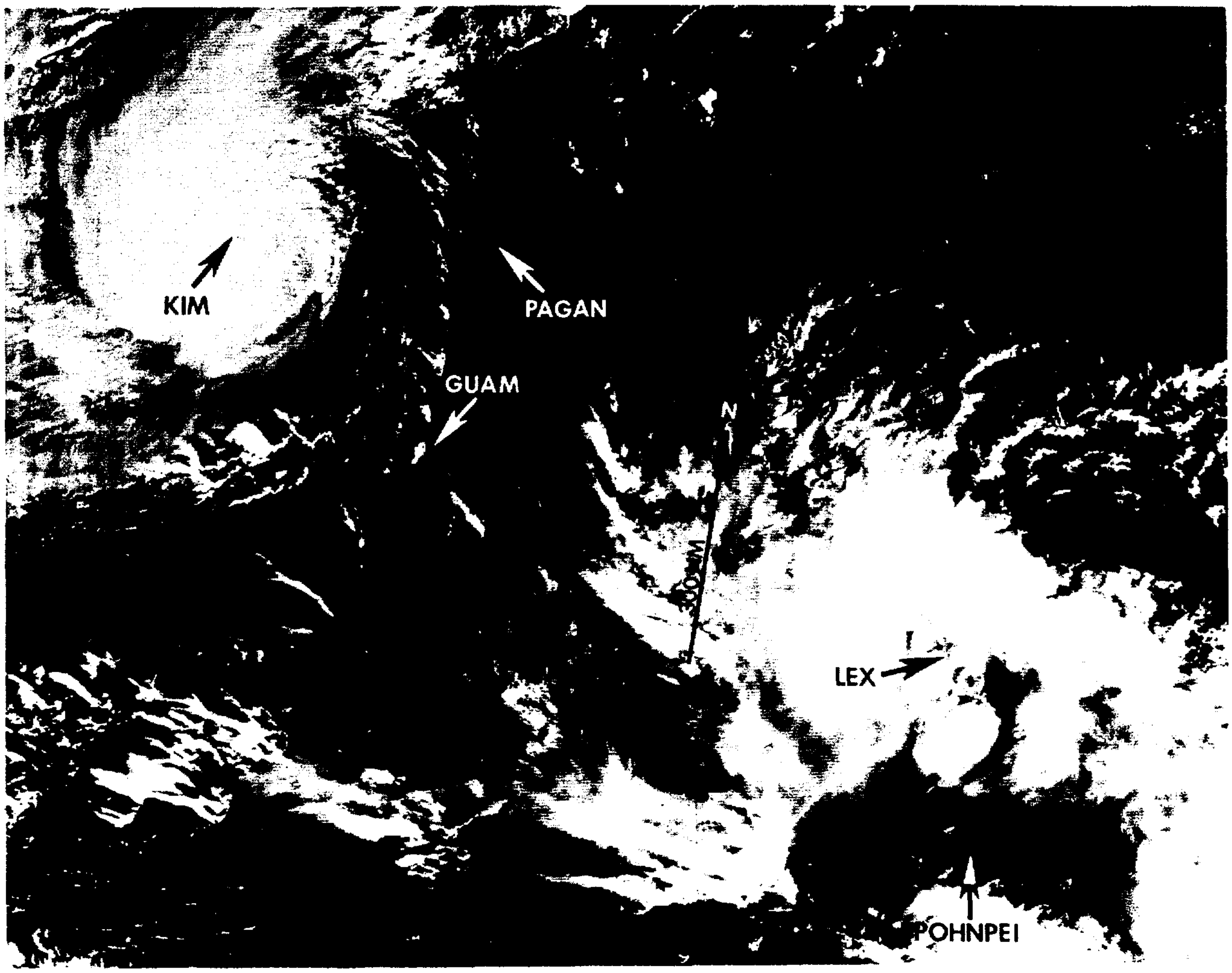


Figure 3-24-1. Visual satellite imagery showing Super Typhoon Kim (23W) and Tropical Storm Lex. The island of Guam is in the region between the two tropical cyclones (042344Z December DMSP visual imagery).

was downgraded to Tropical Depression 24W, and the final warning (number 8) was issued at 051200Z.

JTWC continued to monitor the remnants of Lex. Because of the sudden flare-up of central cold cover (Dvorak, 1984) cloud viewed on the satellite infrared imagery (Figure 3-24-2), Lex again was the subject of a TCFA (062300Z) about 80 nm (148 km) east-southeast of Guam. Due to the proximity to Guam, the prospect of sudden deepening and the uncertainty concerning what was really out there, JTWC diverted a WC-130 aircraft from a fix mission, that was in progress on Kim (23W), to fly an investigative profile on Lex. The results were that Lex's low-level circulation could not be closed off and warnings were not resumed. The weak disturbance moved rapidly by at 28 kt (52 km/hr) and passed directly over the island of Rota located 40 nm (74 km) north-northeast of Guam. Mid- to upper-level shear over the system was strong and the upper-level outflow remained restricted by Super Typhoon Kim (23W). JTWC cancelled the TCFA at 071500Z. The remains of Lex then moved northwestward until 080000Z, then curved northeastward and transitioned to an extratropical system.

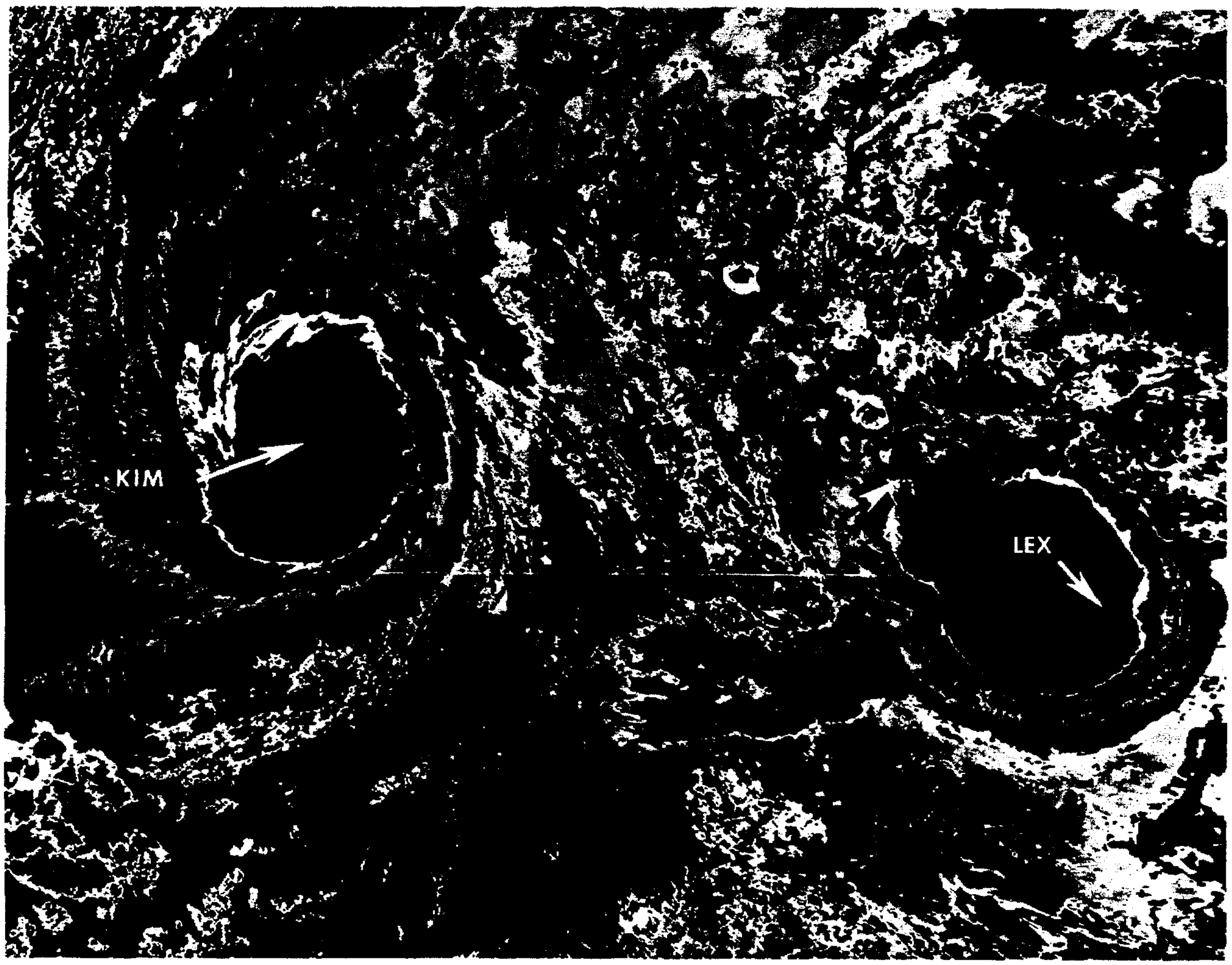
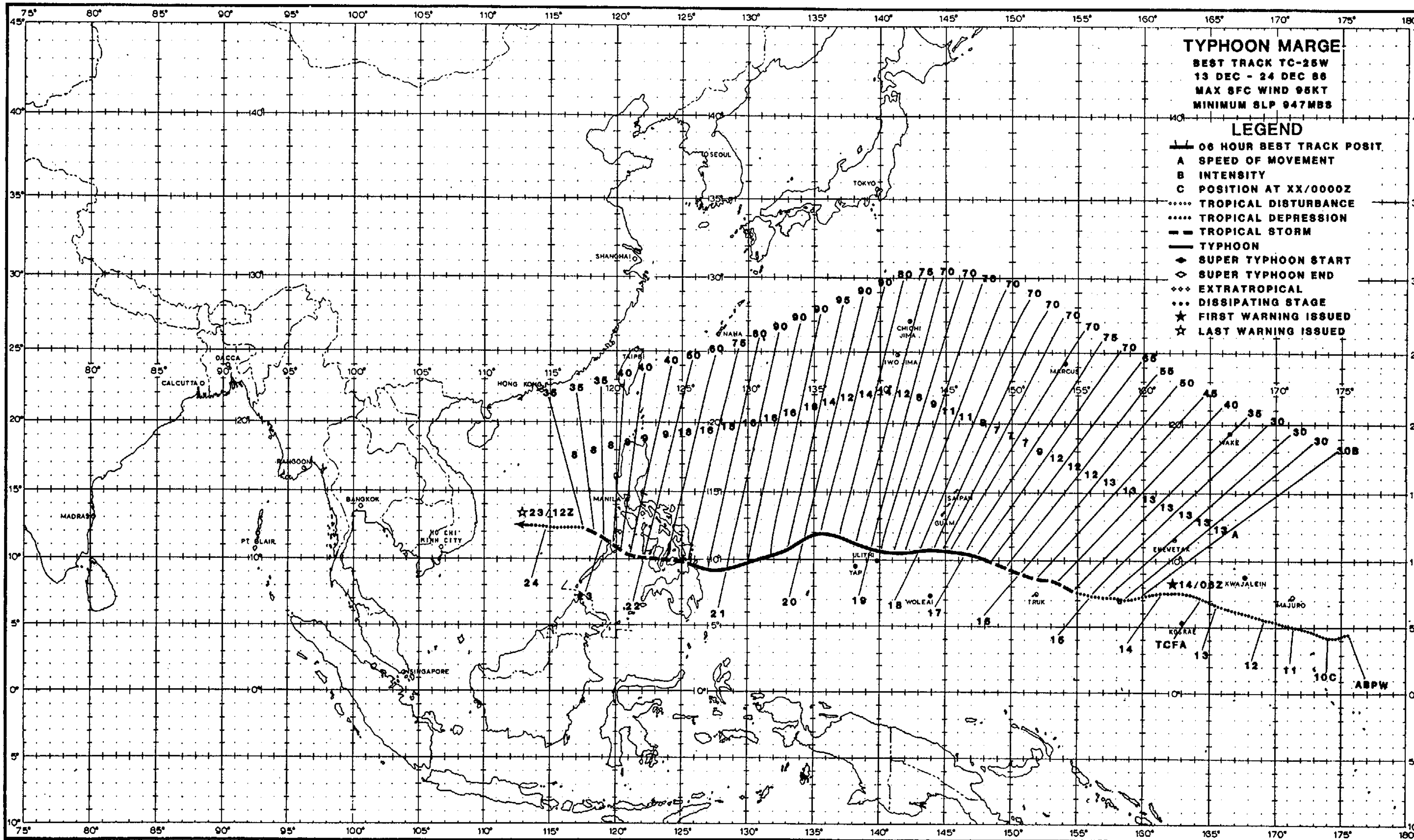


Figure 3-24-2. Enhanced infrared image for the Dvorak intensity estimation technique of the disturbance (Lex) and Kim (23W) at typhoon intensity. At first glance, the cloud signatures look similar. However, the distinction between the transitory flare-up of the central cold cover (Dvorak, 1984) over Lex and the persistent central dense overcast and eye of Kim (23W) is crucial for proper intensity analysis (061758Z December NOAA infrared imagery).



NOCC GUAM 3142/20 (NEW 5 - 80)

Typhoon Marge was a mid-December tropical cyclone that originated in the near-equatorial trough at low latitudes just east of the Marshall Islands. Slow to develop, Typhoon Marge presented a couple of unique forecasting problems which included some unexpected movement in the Philippine Sea.

Referenced for the first time on the Significant Tropical Weather Advisory (ABPW PGTW) on 9 December, the first warning wasn't issued until 140600Z December. During the intervening time, Marge drifted slowly toward the northwest as a large area of disorganized convection. The first Tropical Cyclone Formation Alert valid at 130330Z was based on satellite (Dvorak) intensity estimates of 20 to 30 kt (10 to 15 m/sec) winds and decreasing sea-level pressure. The first warning followed on the 14th and was based on satellite imagery which indicated an increase in convection and upper-level organization. From the 15th through the 16th, Marge's mean track was west-northwestward as the forecasts followed the under-the-ridge scenario.

Based on the Dvorak analysis of satellite imagery at 150300Z, indicating a maximum wind of 35 kt (18 m/sec), Tropical Depression 25W was upgraded to tropical storm intensity (see Figure 3-25-1). The

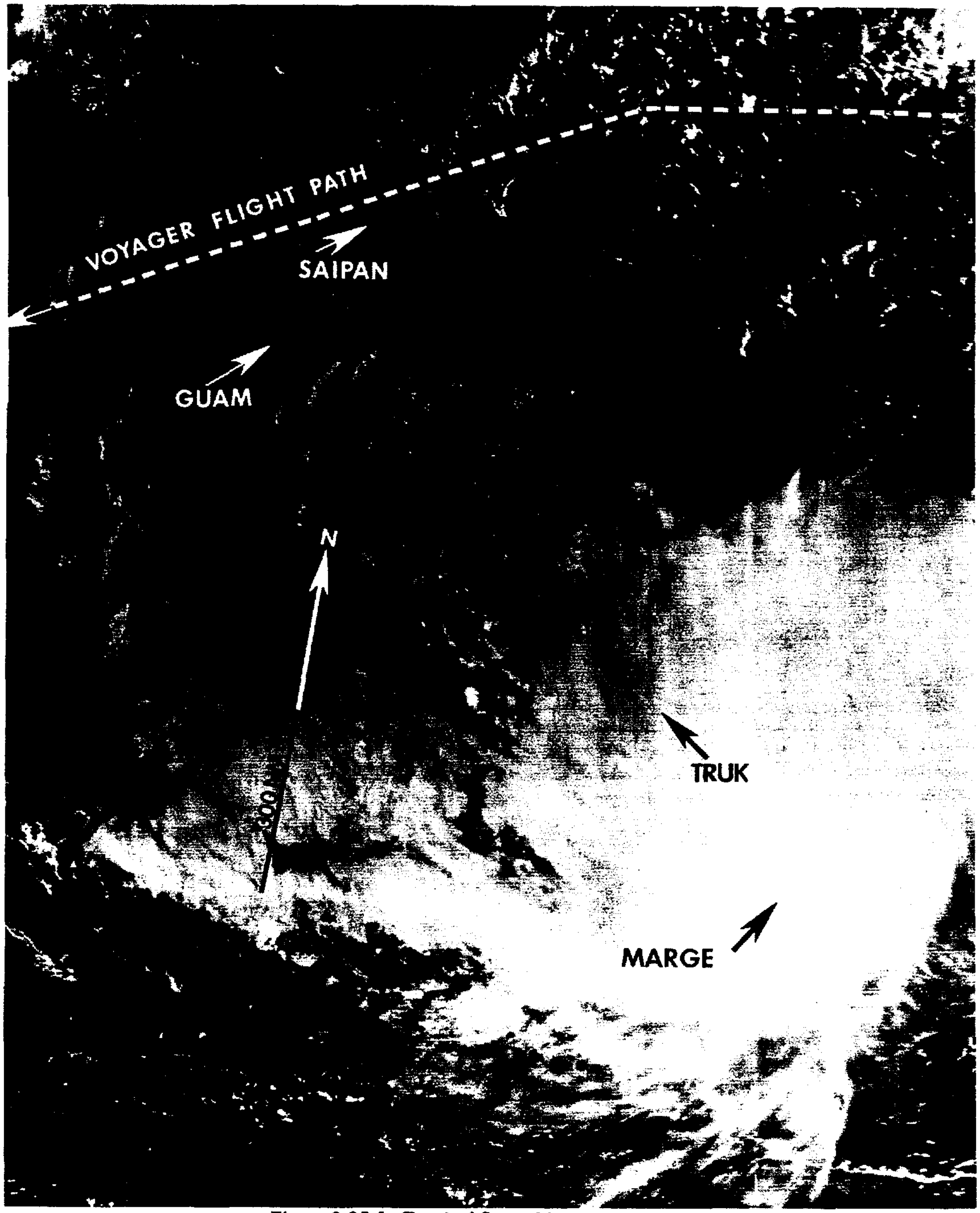


Figure 3-25-1. Tropical Storm Marge passed south of Guam just nine hours before Voyager left on the start of its record-setting flight (150517Z December NOAA visual imagery).

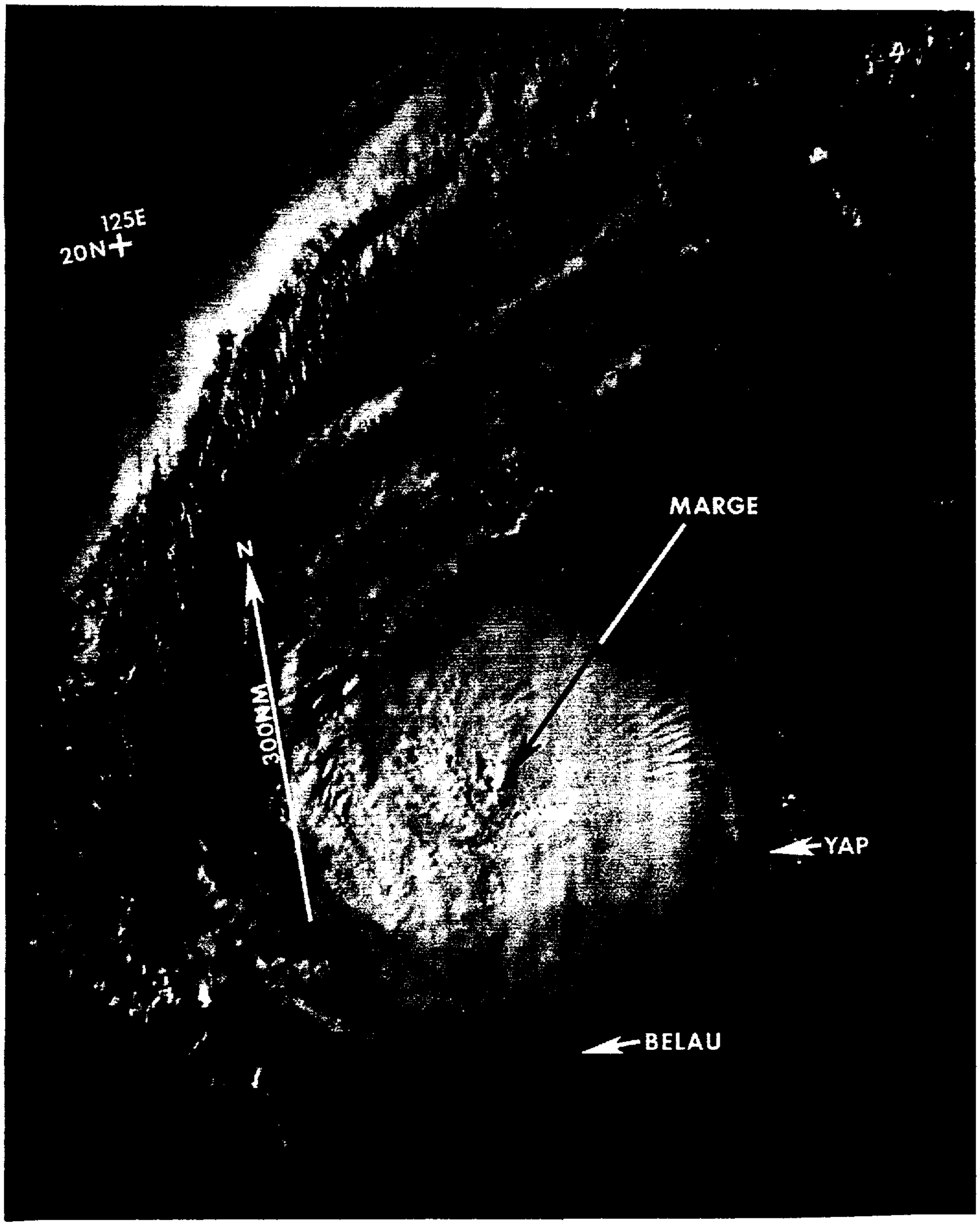


Figure 3-25-2. Marge six hours prior to reaching maximum intensity (192236Z December NOAA visual imagery).

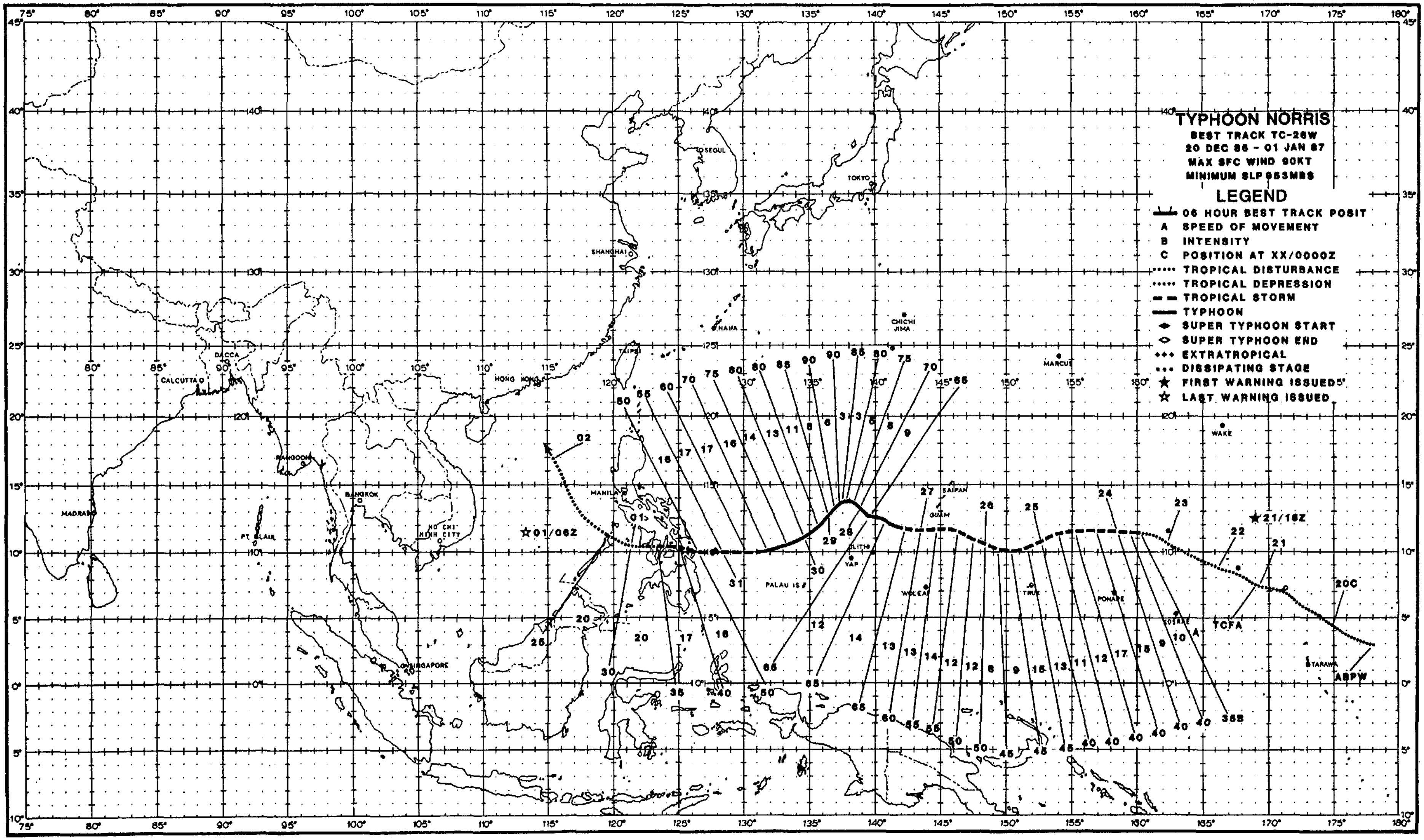
first aircraft reconnaissance mission on the 15th found a minimum sea-level pressure (MSLP) of only 1000 mb, 30 kt (15 m/sec) winds and did not close off a circulation. The next aircraft mission early on the 16th located a vortex with a MSLP of 996 mb and maximum surface winds of 60 kt (31 m/sec). The 161200Z warning upgraded the system to a typhoon.

The first forecast problem with Marge arose at 170000Z, when satellite fixes and aircraft reconnaissance observations began indicating that Marge was no longer moving as forecast toward the west-northwest, but in a more westerly direction. The computer prognostic guidance persisted with the now incorrect west-northwest movement. From 170000Z to 181800Z Marge moved due westward along the edge of the modifying polar air and passed 160 nm (296 km) south of Guam. No evacuations or significant damage to the island occurred.

The next forecast problem arose at 200000Z as Marge began slipping toward the west-southwest. JTWC's initial response was to consider the southward movement as a short-term event and the forecasts reflected this philosophy. This proved to be in error as Marge was forced further southwestward by a strong surge of polar air from the Asian landmass. Marge's unforecast movement in the Philippine Sea caused considerable concern for shipping. For example, the USS Proteus (AS 19) passed within 60 nm (111 km) of the center of Typhoon Marge, circled around its southwest quadrant and experienced winds of 50 kt (26 m/sec) at 210430Z. There was minimal damage to the ship and no personnel were injured. At that time Marge's maximum winds near the center were 80 kt (41 m/sec) and had decreased from a maximum of 95 kt (49 m/sec) earlier at 200600Z (see Figure 3-25-2).

After entering the Philippine Islands, the system weakened and changed course towards the northwest. It then tracked into the South China Sea and dissipated over water.

During Marge's lifetime, aviation history was being made. The Voyager, a light-weight, graphite fiber-bodied aircraft, piloted by Burt Rutan and Jeana Yeager, departed Edwards Air Force Base, California, on 15 December at 1402Z (14 December at 11:02 A.M. EST) in a record-setting attempt to circle the globe on a single tank of fuel. Initially, the flight plan routed Voyager south of the equator, passing just north of Australia on the Pacific portion of the journey. However, a very active monsoon trough present in the western North Pacific at this time forced a change in plans. Following coordination with JTWC, Voyager was rerouted north of the Mariana Islands. While it winged its way west, Marge continued to intensify. Although, at one point it appeared the Voyager might have to terminate its mission, the low-level inflow winds into Marge's center actually aided in the flight. Despite some moderate turbulence, as a consequence of flying between two of Marge's spiral bands to pick up increased tail winds of 35 kt (65 km/hr), Voyager was able to reduce fuel consumption and speed onward to complete a successful mission.



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The final typhoon of 1986, Typhoon Norris, began as Typhoon Marge (25W) was moving through the Caroline Islands and south of Guam. Norris was first detected as a weak low-level circulation in the near-equatorial trough south of the Marshall Islands on 17 December. Initially, an anticyclone aloft at low latitudes near the dateline aided the development of Norris by providing a favorable low-shear environment.

First carried on the Significant Tropical Weather Advisory (ABPW PGTW) on 19 December at 0600Z, the disturbance drifted northwestward while its organization and convection remained minimal. On 20 December, the organization began to improve and at 210300Z, a Tropical Cyclone Formation Alert was issued.

The first warning was issued on 21 December at 1200Z on Tropical Depression 26W when Dvorak analysis of satellite reconnaissance indicated 30 kt (15 m/sec) winds were present (see Figure 3-26-1).

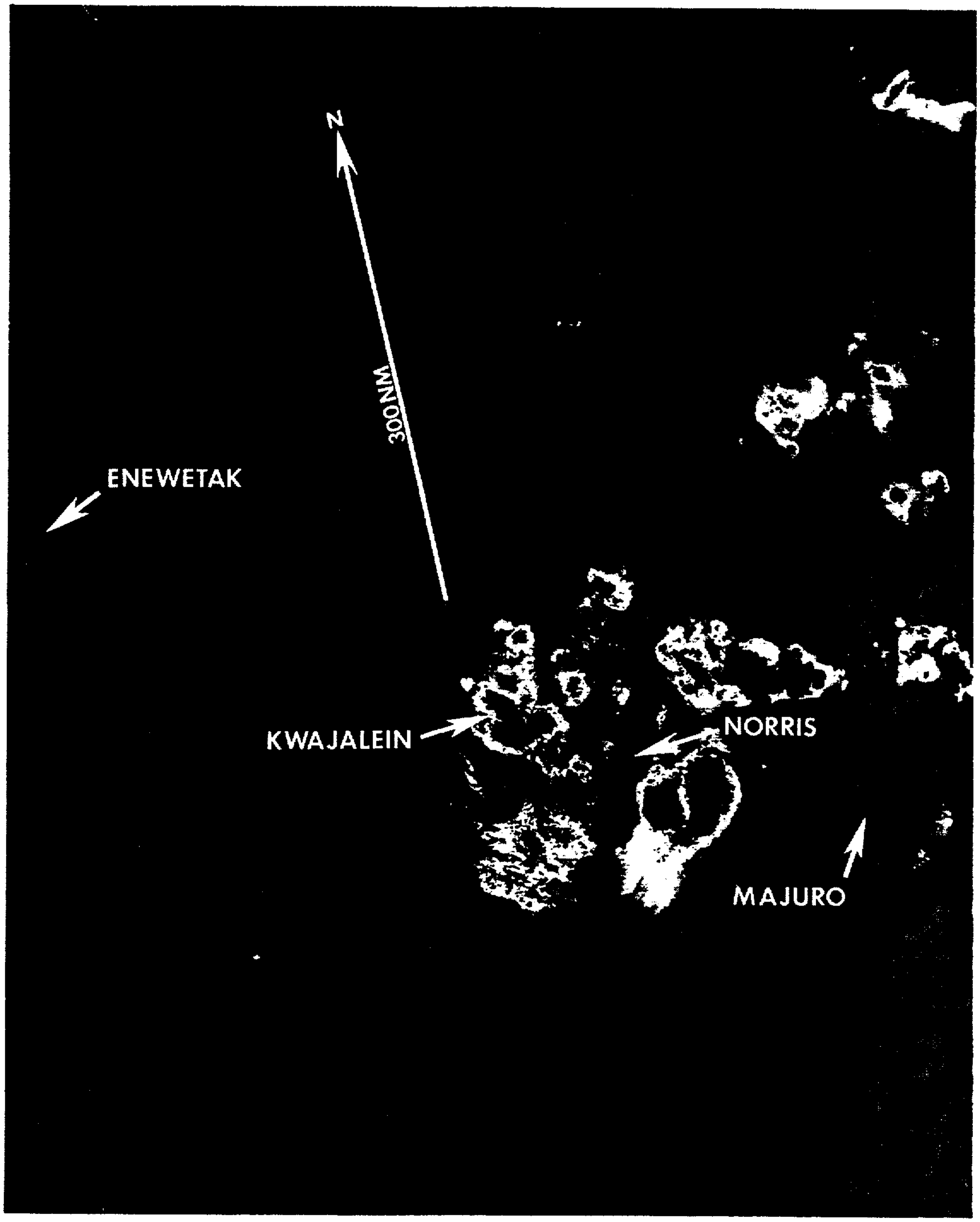


Figure 3-26-1: This enhanced infrared (EIR) image of the tropical disturbance, which ultimately became Typhoon Norris, shows it embedded in the near-equatorial trough (210756Z December DMSP infrared imagery).

Satellite imagery on 22 December revealed an exposed low-level circulation center with the convection displaced approximately 60 nm (111 km) to the west (Figure 3-26-2). Aircraft reconnaissance on the morning of 23 December located the low-level vortex. The Aerial Reconnaissance Weather Officer (ARWO) reported winds of 35 kt (18 m/sec) and a minimum sea-level pressure (MSLP) of 999 mb, which resulted in the upgrade to Tropical Storm Norris (26W) on the 230000Z warning.

From the time Norris began forming in the near-equatorial trough, the system moved steadily toward the northwest following the forecast under-the-ridge scenario. The movement toward the northwest was also influenced by the passage of a mid-latitude trough. On 23 December, the mid-latitude trough had moved to the east of the system and the subtropical ridge began to rebuild. Norris responded and moved westward. In addition, the low-level circulation center had just started to move under the convection (see Figure 3-26-3).

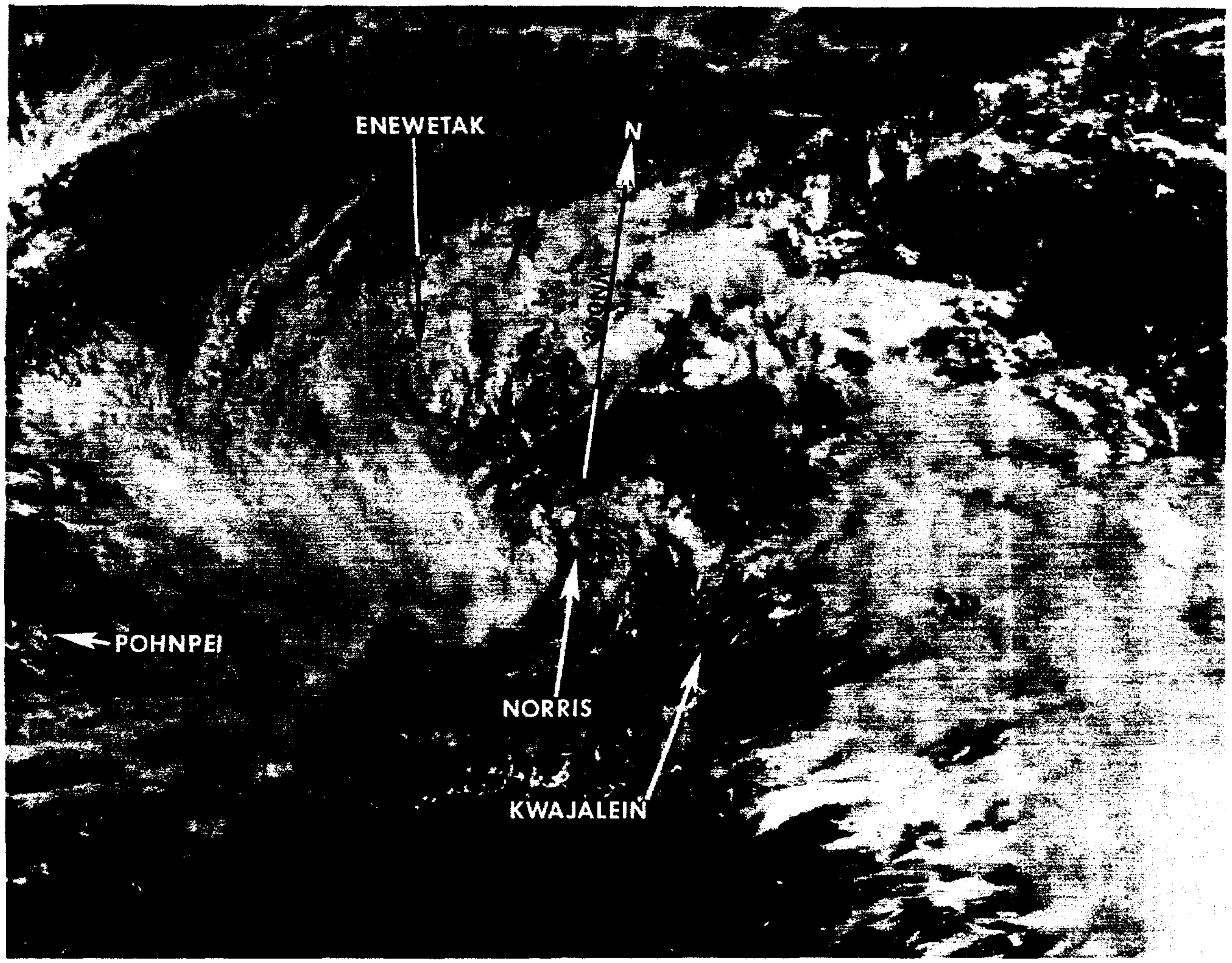


Figure 3-26-2: Vertical shear continues to force the convection towards the west of the low-level circulation center (220400Z December NOAA visual imagery).

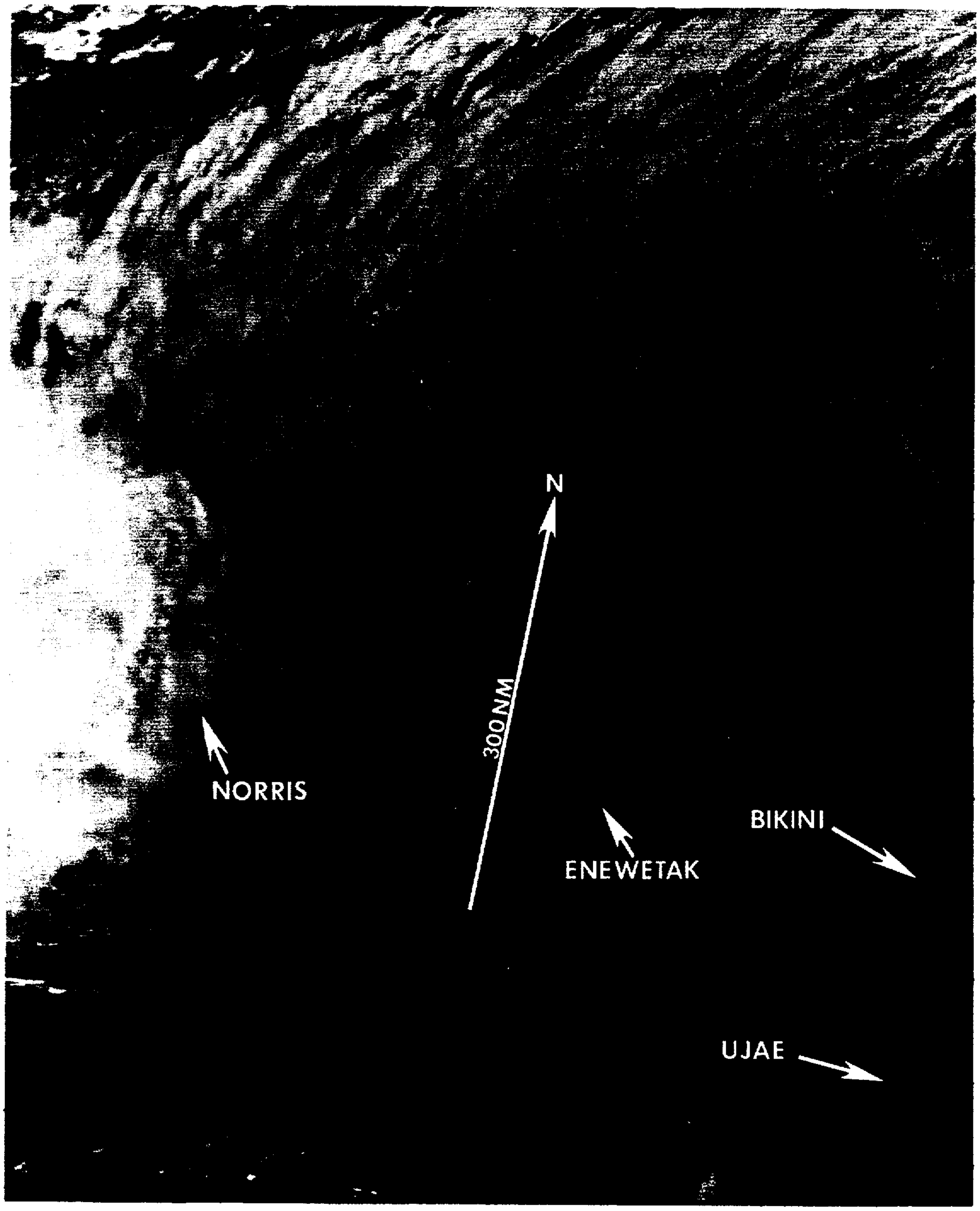


Figure 3-26-3. Tropical Storm Norris still struggling to get organized. The low-level circulation center is beginning to move under the convection (240338Z December NOAA visual imagery).

As the ridge continued to build, Norris began moving away from the forecast track and towards the west-southwest on Christmas Day (Figure 3-26-4). The forecast guidance from the dynamic One-Way Interactive Tropical Cyclone Model (OTCM) and persistence was for westward movement. Within 12-hours the southwestward drift stopped and Norris once again began moving toward the west-northwest. Aircraft reconnaissance on 25 December found the first indications of a developing elliptical-shaped eye.

As Norris moved towards the west-northwest, the system continued to intensify. Winds of typhoon intensity were forecast. Due to a mid-latitude frontal system moving off the Asian mainland, expected adjustment of the subtropical ridge, and an anticipated track change, officials in the southern Marianas braced for the worst. However, aircraft reconnaissance at approximately 261200Z found the movement more westward than west-northwestward. Over the next 12-hours residents of the southern Marianas Islands continued to wait and hope that Norris would miss them. Norris slipped by to the south, passing within 100 nm (185 km) of Guam. Guam experienced 50 kt (26 m/sec) winds and localized flooding, but damage was minimal.

After by-passing Guam and once again moving west-northwestward, Norris continued to develop (see Figure 3-26-5). Based on Dvorak intensity analysis of 65 kt (34 m/sec), Tropical Storm Norris was

Figure 3-26-4: Norris matures and moves toward the west-southwest on Christmas Day (250509Z December NOAA visual imagery).

Figure 3-26-5: Tropical Storm Norris, just prior to its being upgraded to a typhoon (270041Z December DMSP visual imagery).

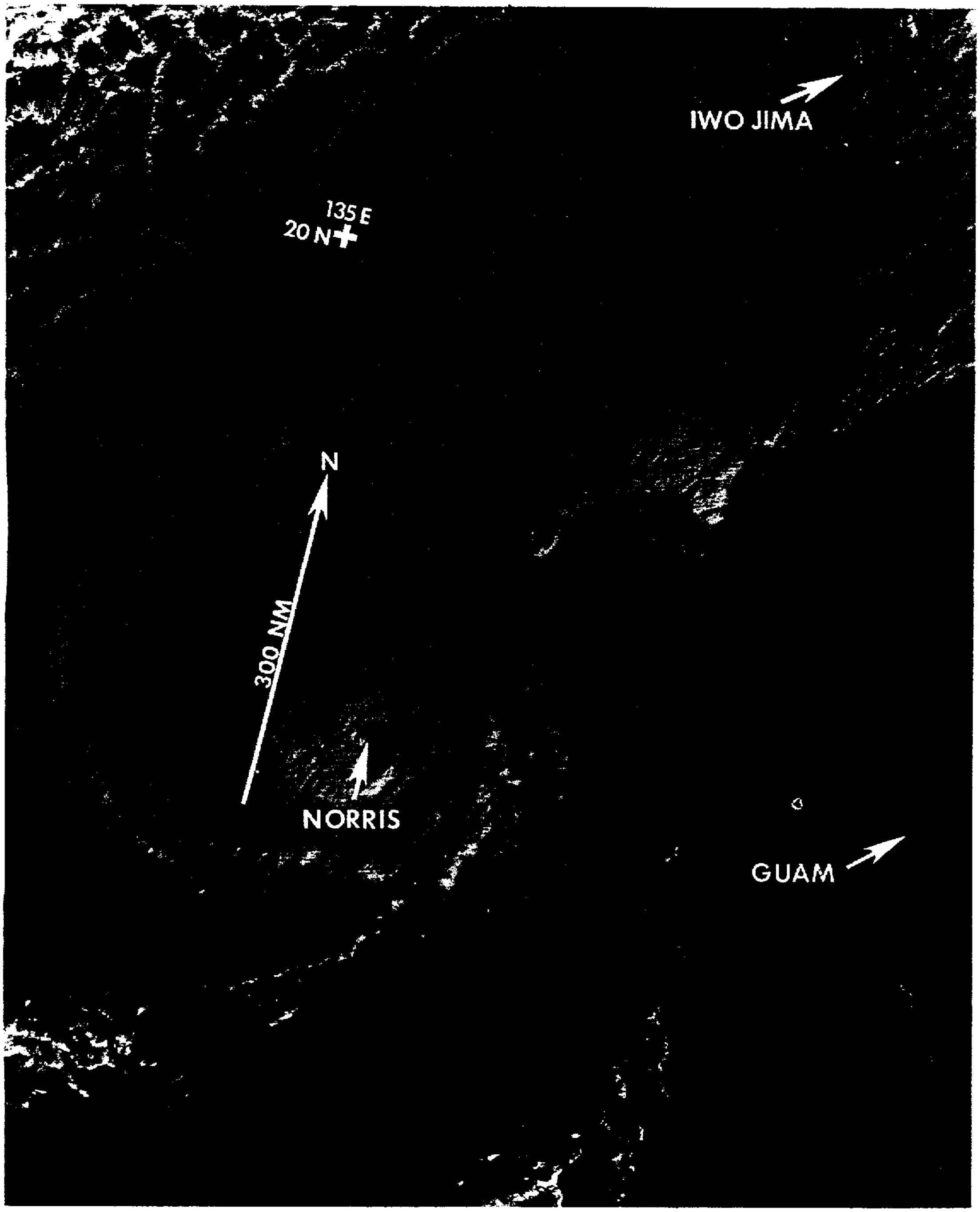


Figure 3-26-6. Typhoon Norris at maximum intensity. The forecast track, until this time, indicated that Norris would recurve and become extratropical (290000Z December DMSP visual imagery).

upgraded to Typhoon Norris at 270600Z. Aircraft reconnaissance at 271101Z reported an eye and a MSLP of 984 mb.

Norris continued moving northwestward toward the weakness in the ridge induced by the passage of a mid-latitude trough moving off the Asian mainland. Previous forecasts had indicated continued movement toward the west-northwest; however, as the mid-latitude trough moved further south and east, Norris' forecast track, starting with the 280600Z warning, was altered to indicate recurvature and extratropical transition.

By 290000Z, the trough moved east and Norris reached maximum intensity (see Figure 3-26-6). The ARWO on the reconnaissance fix mission earlier, at 282103Z, observed 89 kt (46 m/sec) maximum surface winds and a MSLP of 953 mb. Norris, which was caught along the edge of the modifying polar air and northwesterly flow in the Philippine Sea, abruptly changed course and moved southward for 36-hours. Once again the southwesterly course was not forecast or addressed beforehand by the OTCM guidance.

At 301200Z, Norris' track changed to due west as it headed towards the central Philippine Islands (see Figure 3-26-7). After being downgraded to tropical storm intensity at 301800Z, Norris moved into the South China Sea and continued to weaken. By 010300Z January, Norris was further downgraded to a tropical depression. By that time, strong upper-level southeasterly flow had exposed the low-level circulation center. Norris dissipated over water in the South China Sea on January 2nd.

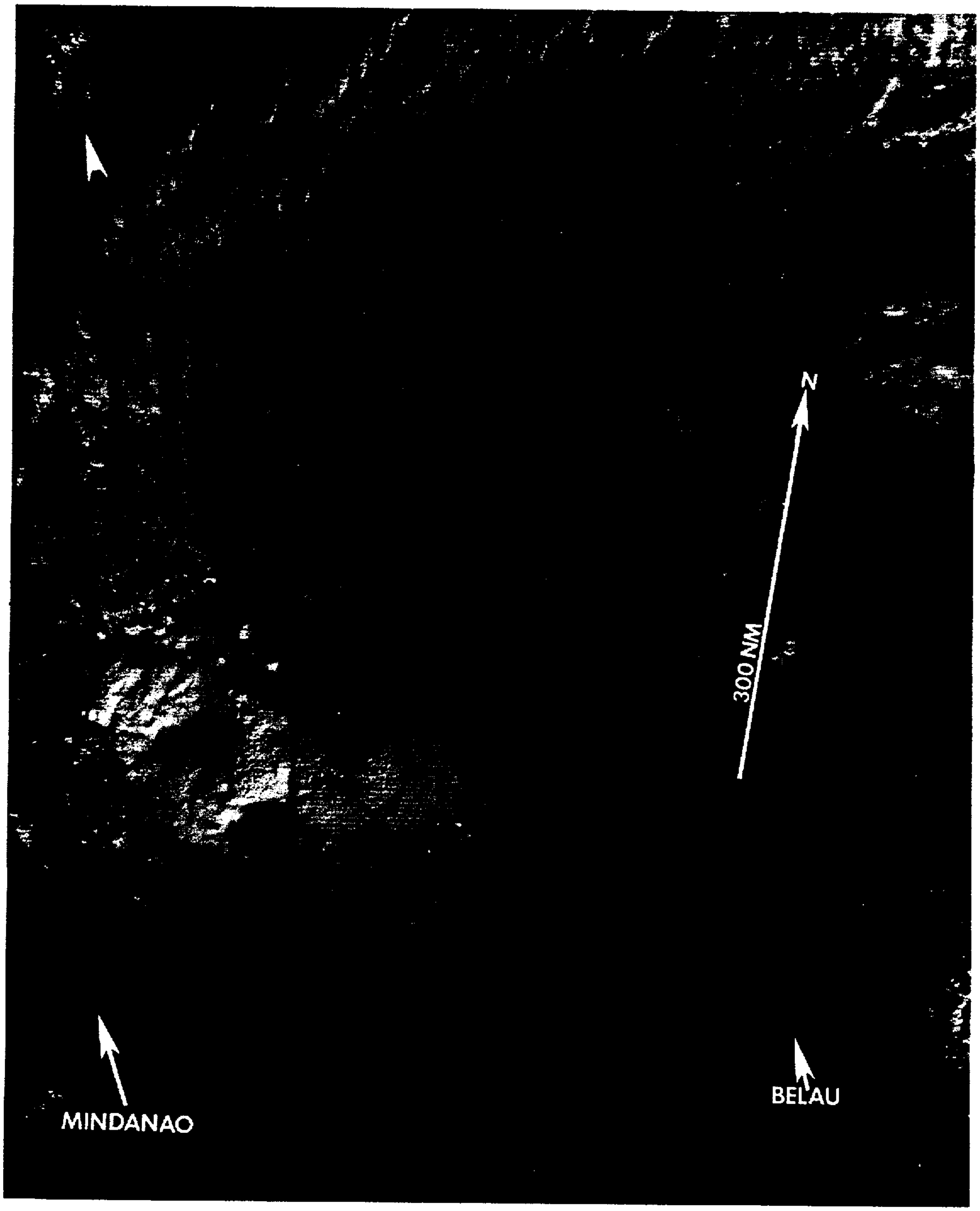


Figure 3-26-7: Tropical Storm Norris approaching the Philippine Islands (310101Z December DMSP visual imagery).

3. NORTH INDIAN OCEAN TROPICAL CYCLONES

Tropical cyclone activity in the North Indian Ocean was slightly below normal. Three significant tropical cyclones, all of tropical storm intensity, developed as compared to the climatological mean of four. These systems occurred in the spring and fall transition seasons, which normally encompasses the peak of the activity. Tables 3-5 and 3-6 provide a summary of information for 1986 and comparison with earlier years.

TABLE 3-5.

NORTH INDIAN OCEAN
1986 SIGNIFICANT TROPICAL CYCLONES

TROPICAL CYCLONE	PERIOD OF WARNING	CALENDAR DAYS OF WARNING	NUMBER OF WARNINGS ISSUED	MAXIMUM SURFACE WINDS-KT (M/S)	ESTIMATED MSLP - MB
TC 01B	07 JAN - 11 JAN	5	17	45 (23)	991
TC 02B	09 NOV	1	2	50 (26)	989
TC 03A	09 NOV - 11 NOV	3	9	45 (23)	990
	1986 TOTALS:	8 *	28		

* OVERLAPPING DAYS INCLUDED ONLY ONCE IN SUM.

TABLE 3-6. FREQUENCY OF NORTH INDIAN OCEAN TROPICAL CYCLONES

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL
1971*	-	-	-	-	-	0	0	0	0	1	1	0	2
1972*	0	0	0	1	0	0	0	0	2	0	1	0	4
1973*	0	0	0	0	0	0	0	0	0	1	2	1	4
1974*	0	0	0	0	0	0	0	0	0	0	1	0	1
1975	1	0	0	0	2	0	0	0	0	1	2	0	6
1976	0	0	0	1	0	1	0	0	1	1	0	1	5
1977	0	0	0	0	1	1	0	0	0	1	2	0	5
1978	0	0	0	0	1	0	0	0	0	1	2	0	4
1979	0	0	0	0	1	1	0	0	2	1	2	0	7
1980	0	0	0	0	0	0	0	0	0	0	1	1	2
1981	0	0	0	0	0	0	0	0	0	1	1	1	3
1982	0	0	0	0	1	1	0	0	0	2	1	0	5
1983	0	0	0	0	0	0	0	1	0	1	1	0	3
1984	0	0	0	0	1	0	0	0	0	1	2	0	4
1985	0	0	0	0	2	0	0	0	0	2	1	1	6
1986	1	0	0	0	0	0	0	0	0	0	2	0	3
(1975-1986) AVERAGE	0.2	0.0	0.0	0.1	0.8	0.3	0.0	0.1	0.3	1.0	1.4	0.3	4.4
CASES	2	0	0	1	9	4	0	1	3	12	17	4	53

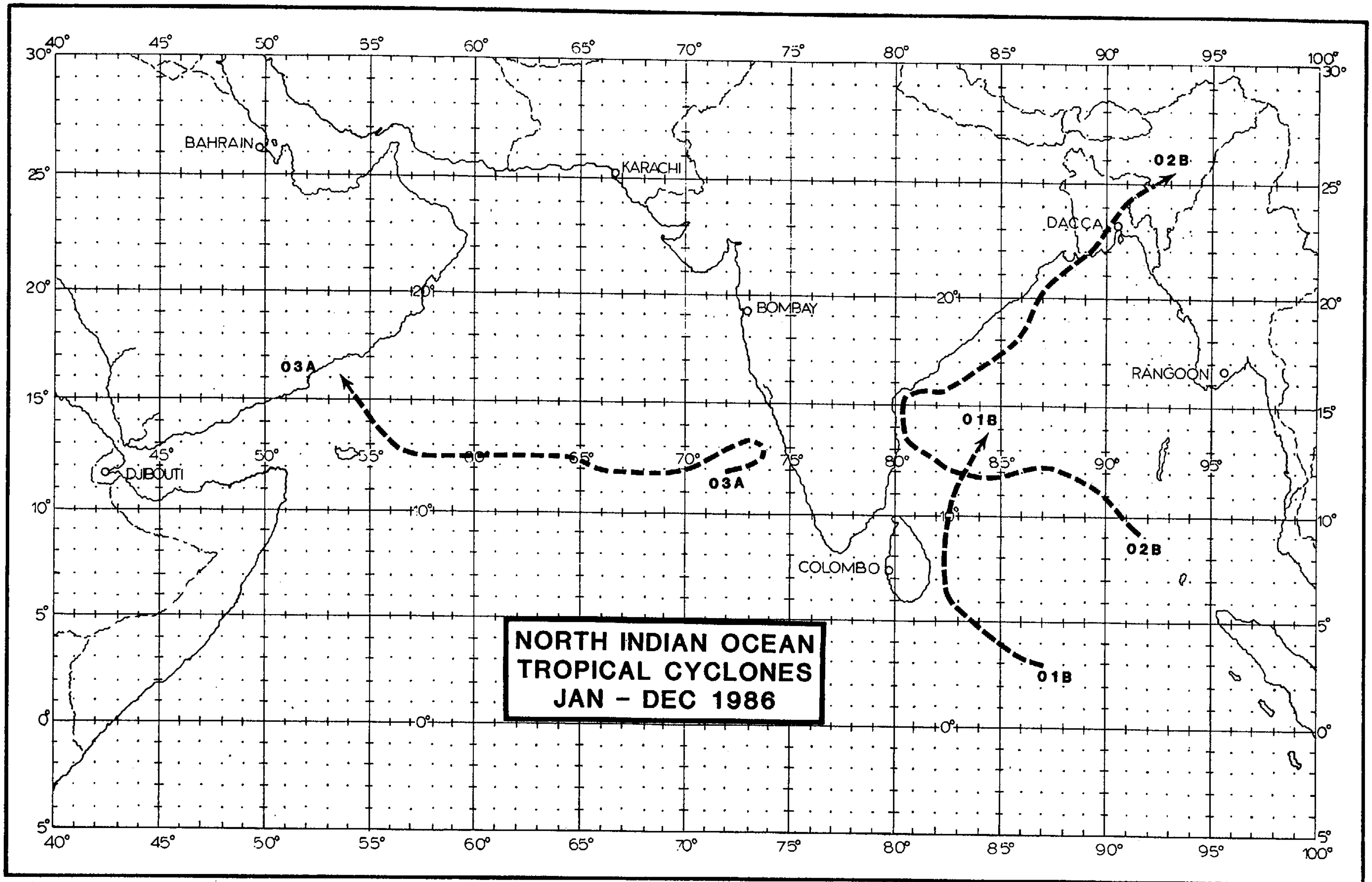
* JTWC WARNING RESPONSIBILITY BEGAN ON 4 JUN 71 FOR THE BAY OF BENGAL, EAST OF 90 DEGREES EAST LONGITUDE. AS DIRECTED BY CINCPAC, JTWC ISSUED WARNINGS ONLY FOR THOSE TROPICAL CYCLONES THAT DEVELOPED OR TRACKED THROUGH THAT PORTION OF THE BAY OF BENGAL. COMMENCING WITH THE 1975 TROPICAL CYCLONE SEASON, JTWC'S AREA OF RESPONSIBILITY WAS EXTENDED WESTWARD TO INCLUDE THE WESTERN PORTION OF THE BAY OF BENGAL AND THE ENTIRE ARABIAN SEA.

FORMATION ALERTS: 3 OF 9 FORMATION ALERTS DEVELOPED INTO SIGNIFICANT TROPICAL CYCLONES. TROPICAL CYCLONE FORMATION ALERTS WERE ISSUED FOR ALL OF THE SIGNIFICANT TROPICAL CYCLONES THAT DEVELOPED IN 1986.

WARNINGS: NUMBER OF CALENDAR WARNING DAYS: 8

NUMBER OF CALENDAR WARNING DAYS WITH TWO TROPICAL CYCLONES: 1

NUMBER OF CALENDAR WARNING DAYS WITH THREE TROPICAL CYCLONES: 0



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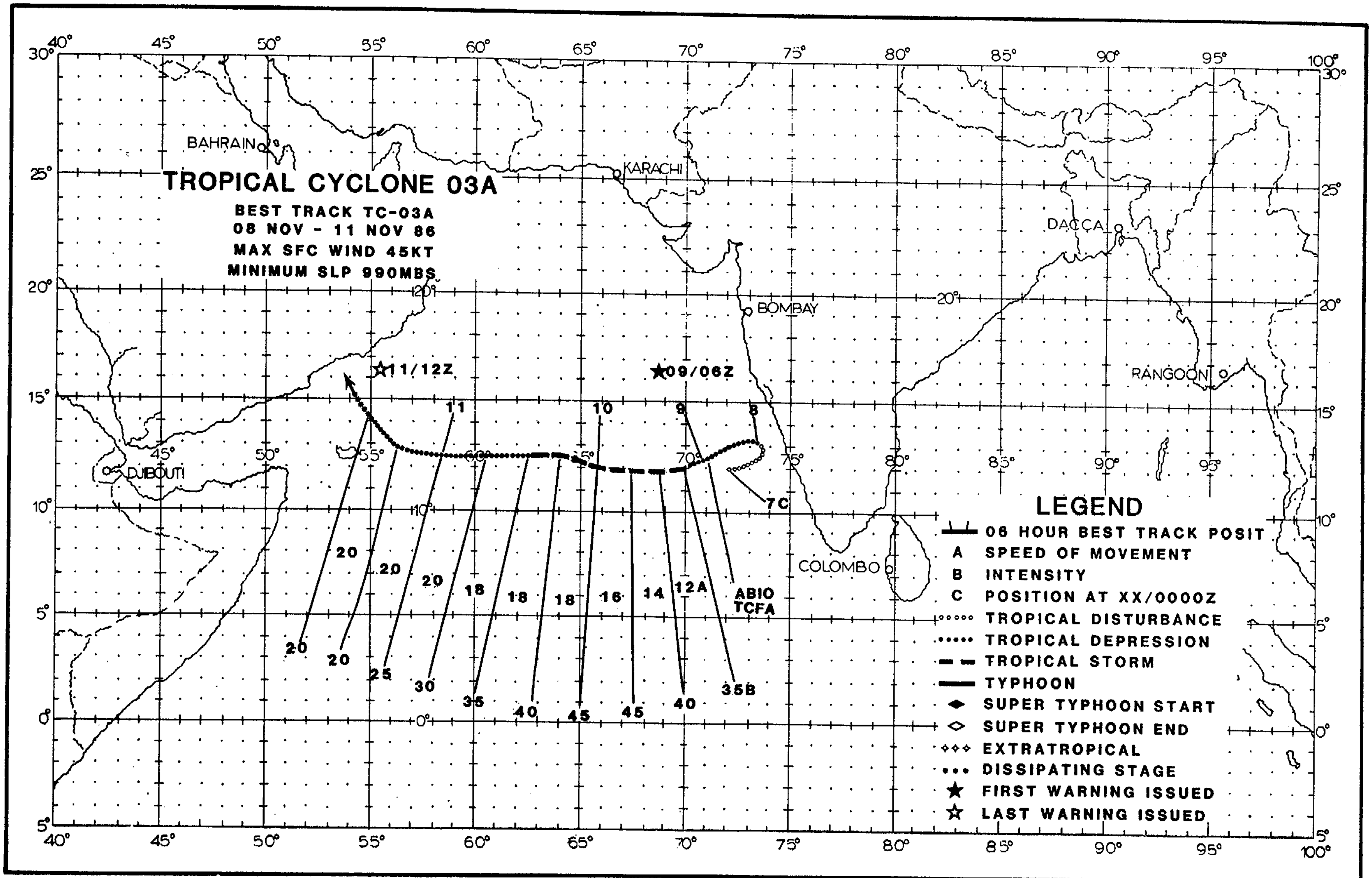
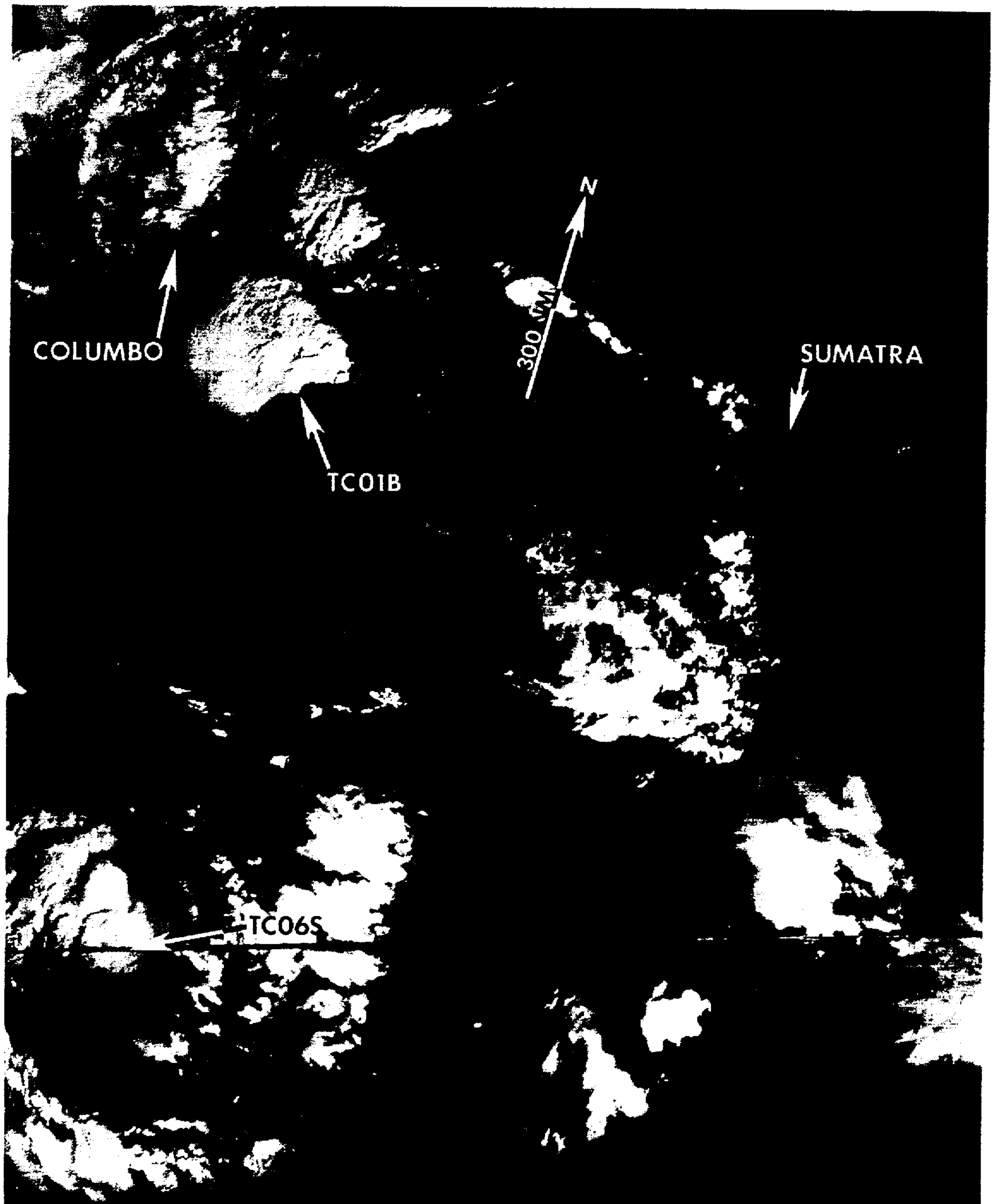
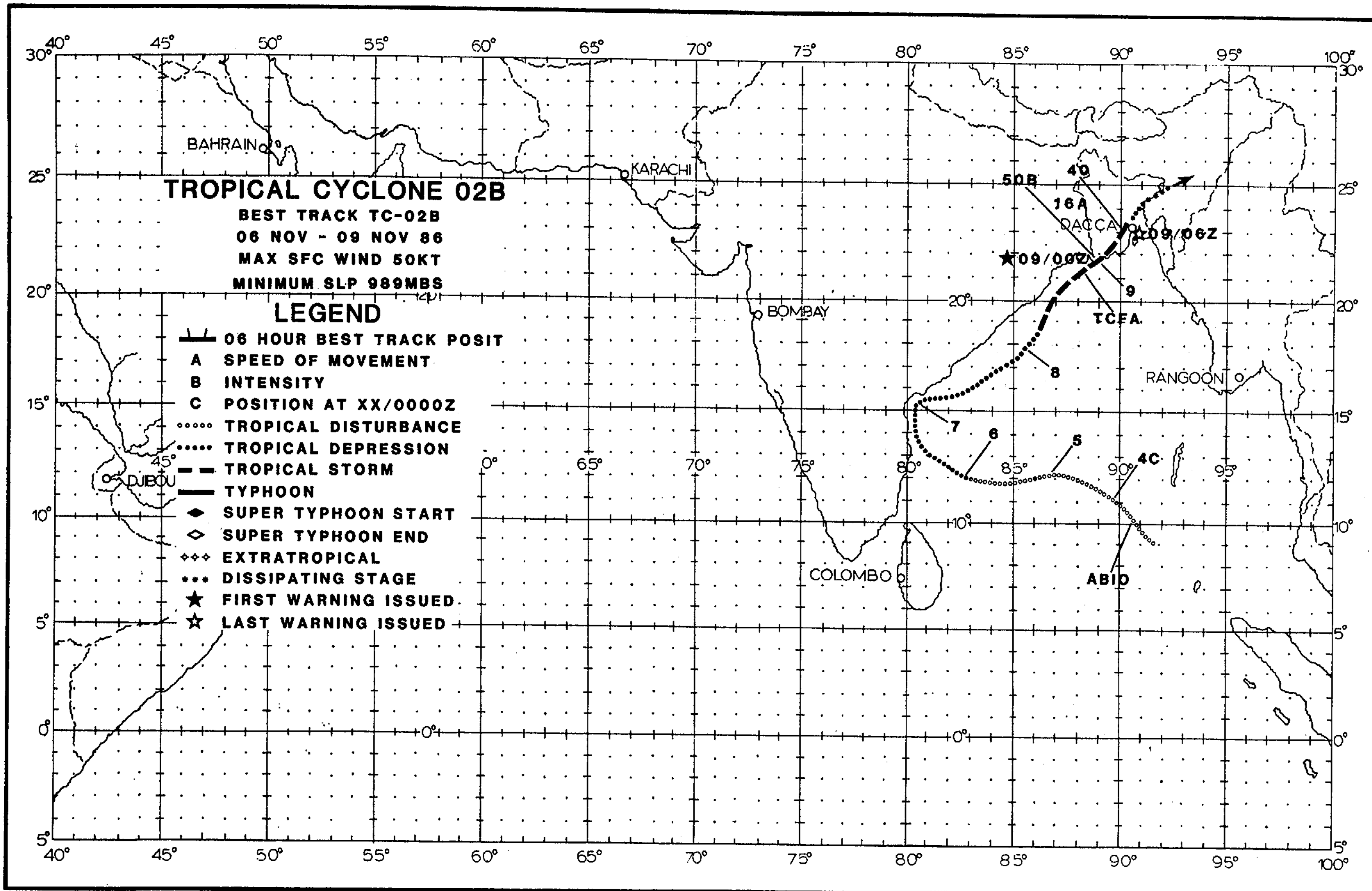


FWC/JTWC GUAM 3142/62 (NEW 2-76)

Figure 3-01B-1. The partially exposed low-level center of Tropical Cyclone 01B was located southeast of Sri Lanka on the 8th of January. The system was being sheared by upper-level flow associated with Tropical Cyclone 04S to the south, which was at typhoon intensity (080404Z January DMSP visual imagery).





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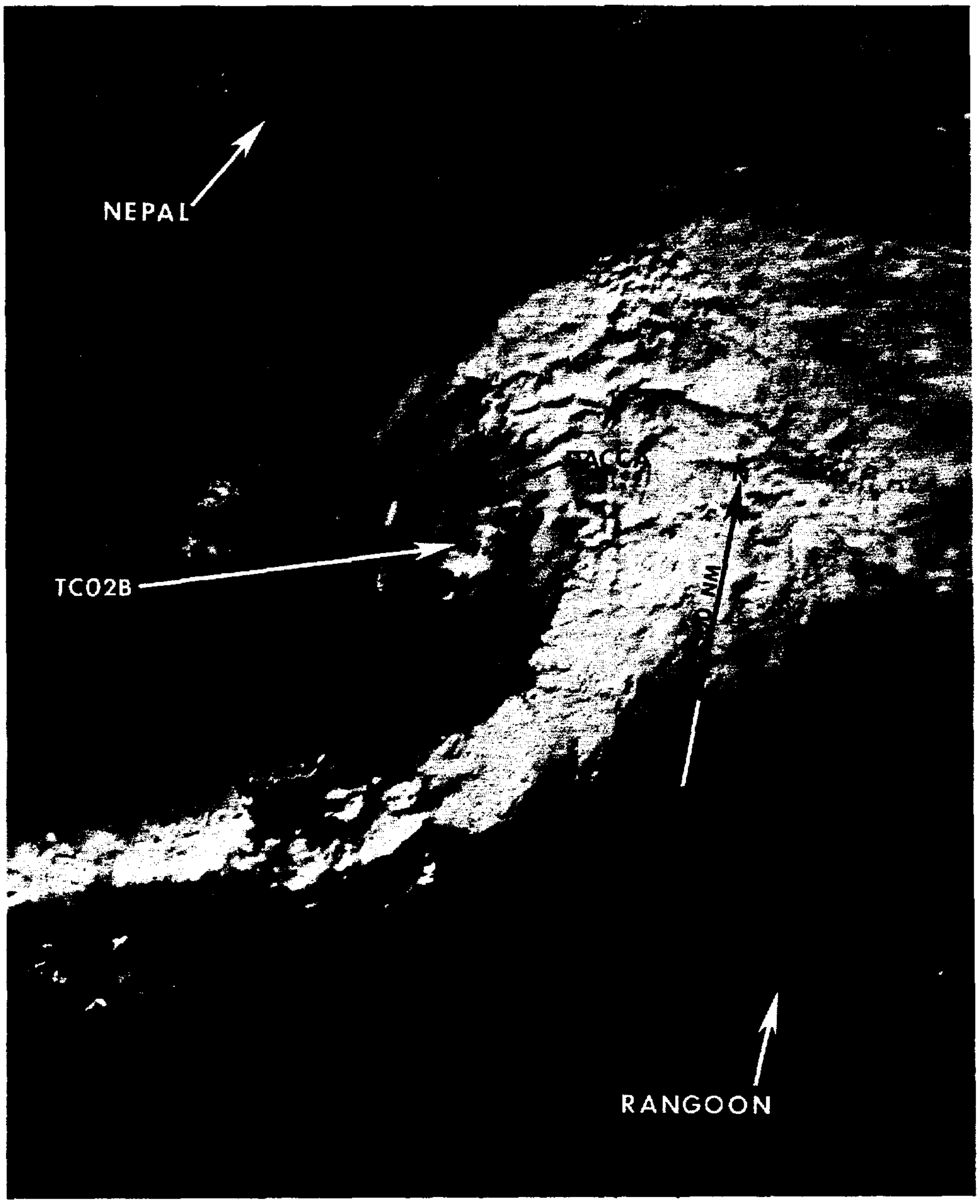
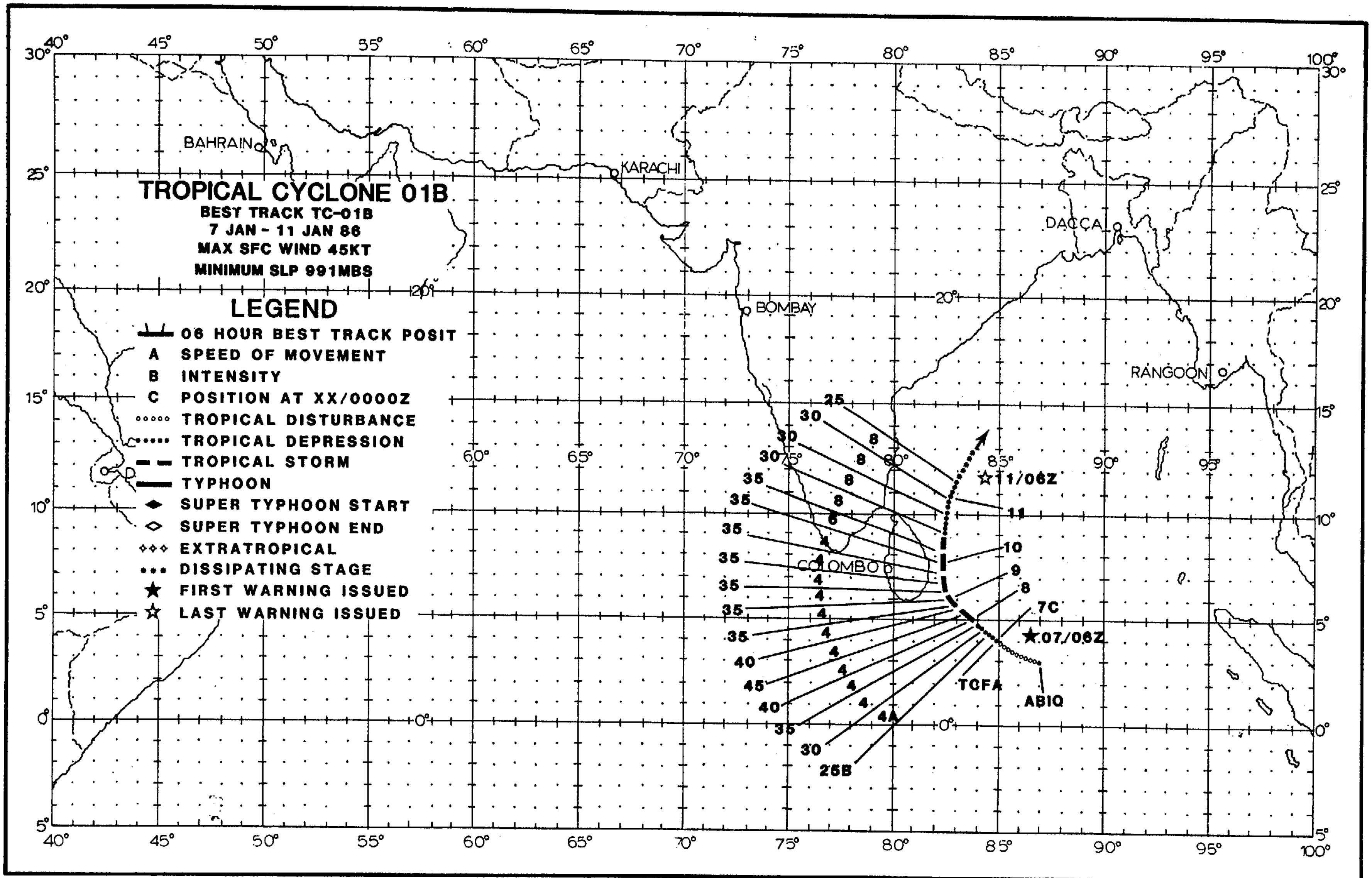


Figure 3-02B-1. Tropical Cyclone 02B was the only tropical cyclone to develop in the Bay of Bengal during the fall transition season. Two warnings were issued on the system. It began on 3 November as a disturbance in the Bay of Bengal approximately 60 nm (111 km) west of the Nicobar Islands. Over the next three days the disturbance continued to slowly intensify as it tracked toward the west. The disturbance then curved northward and skirted the Indian coast. Post analysis indicated tropical storm intensity had been attained 12-hours prior to the issuance of the first warning at 090000Z. Tropical Cyclone 02B continued on its northeastward track and immediately made landfall at the Ganges River Delta in Bangladesh at 090000Z. The maximum intensity of 50 kt (26 m/sec) was reached just prior to striking the coast. After landfall, Tropical Cyclone 02B weakened rapidly. Damage to the coastal villages in Bangladesh was substantial. Officials reported 11 dead and at least fifty others missing as a result of heavy flooding and wind gusts of up to 65 kt (33 m/sec). The image above shows Tropical Cyclone 02B three hours after landfall (090331Z November DMSP visual imagery).



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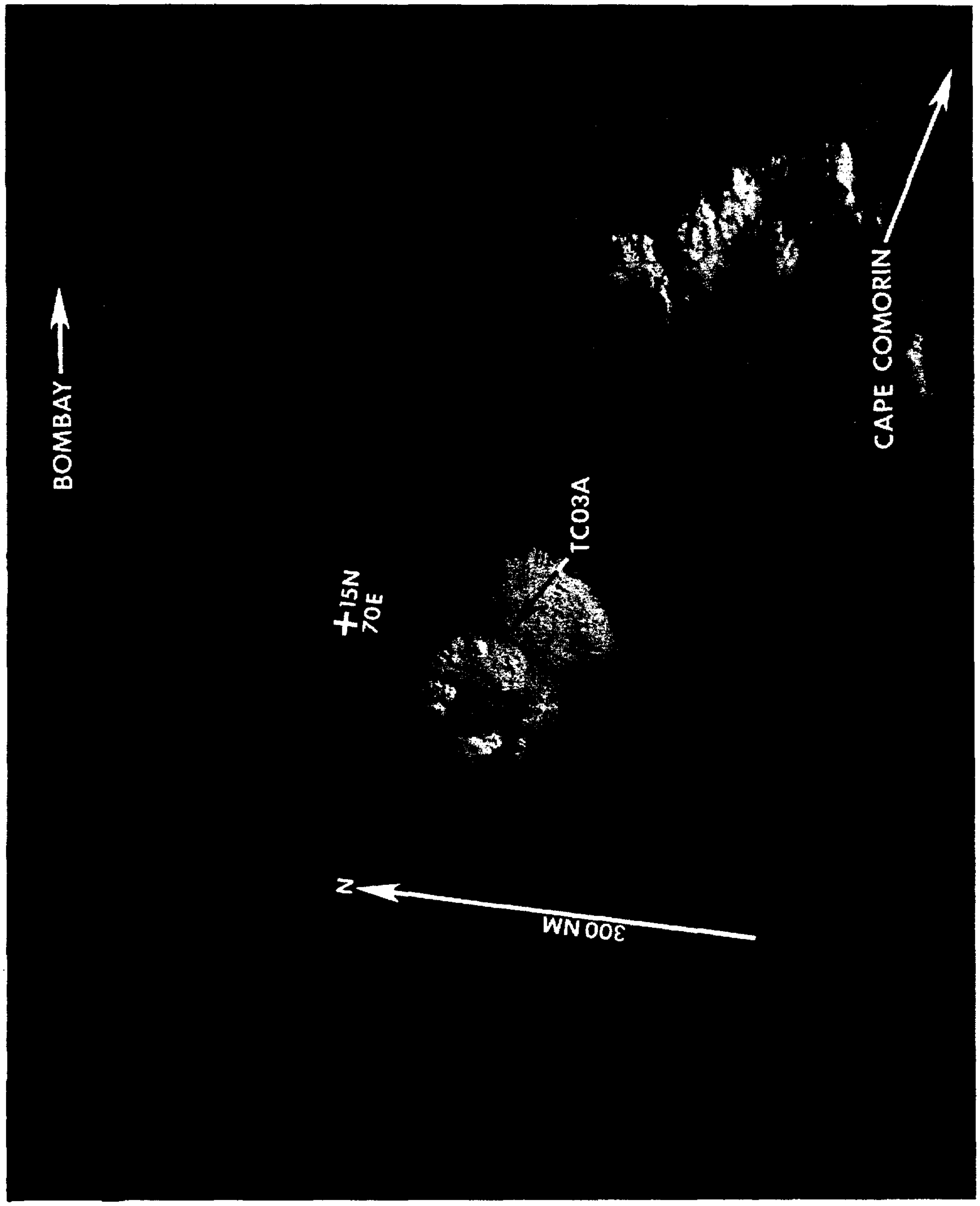

Figure 3-03A-1. Tropical Cyclone 03A was the only significant tropical cyclone to develop in the Arabian Sea in 1986. It was first carried on the Significant Tropical Cyclone Weather Advisory (ABIO PGTW) on November 1st when the area rapidly improved in organization. On November 2nd, the first Tropical Cyclone Formation Alert (TCFA) was issued. Shear over the disturbance suppressed development by separating the low-level circulation center and the upper-level anticyclone. On 6 November, the TCFA was cancelled after both the convection and organization had decreased. Satellite imagery indicated the anticyclone was no longer evident and the upper-level flow was unidirectional over the disturbance. However, on 8 November, redevelopment occurred. Dvorak intensity analysis of satellite imagery, at 080532Z, indicated winds of 35 kt (18 m/sec). Satellite imagery 12-hours later indicated winds of 45 kt (23 m/sec). JTWC issued its first warning on Tropical Cyclone 03A at 090600Z. Four hours after the first warning was issued, satellite imagery once again indicated shear over the cyclone with a separation of 75 nm (139 km) between the low-level and upper-level circulation centers. JTWC issued the final warning at 111200Z, after Tropical Cyclone 03A lost all of its convection. Tropical Cyclone 03A dissipated over water. There were no reports of damage. The satellite picture shows Tropical Cyclone 03A in the Arabian Sea one hour before the first warning was issued (090512Z November DMSP visual imagery).